# THE TECH ENGINEERING NEWS

*Massachusetts Institute of Technology • 1937 •* *May*

WORN SCREW-CONVEYOR flights rebuilt by bronze-welding save replacement costs.

# Build up the worn down . . .

## Previous habits in the metals field reversed by new welding technique

UNTIL a comparatively short time ago, when metal parts were worn below the limit of tolerance, they were discarded. Further cutting down could not make them fit the job again. This method wasted both time and money.

With the introduction of welding, this picture has been entirely changed. It is easy now to build up metal at low cost. Parts, worn too small to be useful, can be returned to original size and shape. By the oxy-acetylene welding process, new metal is put on where the old has been worn away. The original investment may thus be salvaged by a small additional investment in repair by welding.

### Welding Means Low-Cost Repairs

Welding has made rapid strides in the repair and rebuilding of worn parts. In every industry where metal is used and wear occurs, welding methods are saving money. Oil-well drills can now be kept in cutting shape long after their normal life span is past. Railroad shops repair and rebuild worn parts of rolling stock and track by welding as a regular procedure. Factory tools and machinery are kept in shape through welding as one of the surest ways to low-cost, profitable operation. Contractors and engineers rely on welding to rebuild worn drill bits, picks, shafting and wearing parts on shovels and digging equipment. The list of repairs made by welding is growing rapidly.

### A Friend in Need

Welding is indeed a friend in need. For example, when work is being done on time contracts, it is of vital importance that worn or damaged equipment can be repaired quickly on the job. Suspension of operations until new parts could be obtained would be fatal to speed and profit. With welding, such interruptions are prevented since machinery and equipment are kept continually in operating trim. The scrap piles are kept at a low ebb. Worn metal parts, from shovel dipper teeth to truck axles, are reclaimed by welding. It can be depended upon to give satisfactory results in repair, maintenance and fabrication.

## Welding Savings

$2,000 budgeted for new saws was saved by welding. Before any money was spent, the company checked into the possibilities of welding. Saw-repair by welding was developed, and now saws with broken teeth, cracks or other damage are restored at a fraction of the cost of new saws.

* * *

Welding of the copper kettles used for boiling wax in chemical and dye manufacture has become a regular routine that saves a chemical company many hundreds of dollars. After being in service for some time, the bottoms of these kettles become very thin. As the kettles have both an inner and outer shell, it was found best to weld in two new bottoms.

* * *

Welding was used by a midwestern creamery to rebuild the teeth on a large gear. The gear was worth $600, and the rebuilding work cost less than $50. This one job alone far more than paid for all necessary welding equipment.

* * *

Welding saves thousands of dollars each year for a large western railroad. Battered rail ends, caused by constant hammering of the car wheels at the joints, are rebuilt by welding. The rail ends are welded in place without traffic interruption. This saves taking up the rails, sawing off the ends, redrilling and relaying.

* * *

Welding is used to reclaim worn and broken reamers from automobile shops. The reamers, which cost from $2.50 to $16 each, reclaimed by welding are as good as new, at an average cost of 40 cents. Breakage and loss of teeth on this type of tool are extremely high. The tooth bill in these shops has shown a healthy reduction since welding methods have been used.

* * *

In a wood-products mill, welding is used to rebuild the steel shafts in pulp grinders. These shafts, originally a foot in diameter, wear rapidly and continually at the collars holding the stone. A small amount of play makes it difficult to keep the collars drawn up tight. Under these conditions, wear happens fast. Common practice, before the advent of welding, was to change the collars and bearing four to eight times as the shaft wore down and was remachined. When the shaft was too small, about eight inches in diameter, it was discarded. Now by welding, the shaft is built up to original size as soon as it wears. Many thousands of dollars in new shafts, collars and bearings are saved annually.

* * *

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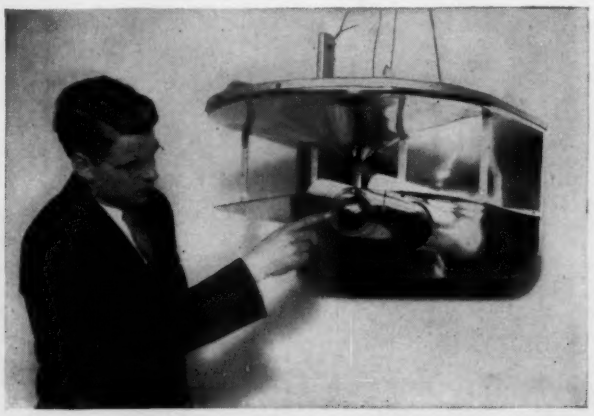
# Glare On the Highways

## *Illuminating Engineering Tackles the Problem*

PARRY MOON

THE rapid emergence of modern civilization from the horse-and-buggy days has brought with it a host of puzzling problems, not the least of which is the problem of lighting our highways. For a driver going ten miles an hour, almost any kind of lamp suffices to prevent him from running off the pavement or from hitting obstacles. For a driver traveling 50 miles an hour at night, the visual requirements are severe and the lighting problem is obviously quite different from anything encountered before in the lighting art. Moreover, it is not made appreciably easier by dazzling glare



—*All illustrations courtesy General Electric Company.*

***A G-E sodium-vapor lamp, 10,000 lumens, in fixture.***

from other cars, by complicated arrays of traffic signals, or by roadside advertising signs of all colors.

An idea of the vital importance of the subject is given by accident statistics. According to the National Safety Council, approximately 37,000 people are being killed in the United States each year by motor vehicles, which number constitutes almost 40 per cent of the total number of accidental deaths from *all* causes. Despite safety campaigns, motor vehicle fatalities are increasing steadily while accidents from practically all other causes are decreasing. The data show also that the ratio of automobile accidents to traffic count is much higher at night than in the daytime. There seems to be no definite way of telling how much of this effect is caused by the greater proportion of commercial traffic in the daytime or the greater amount of drunken driving at night. Certainly one cannot concur with those salesmen of street-lighting luminaires who state that 10,000 lives could be saved each year if a sufficient number of their luminaires were installed on the highways. Nevertheless, there is every reason to believe that adequate lighting would be distinctly helpful in increasing highway safety. The problem is one that touches every one of us only too closely.

Two general methods of illumination are available:

(a) Lighting by fixed lamps, as in our present systems for city streets.

(b) Lighting by movable lamps attached to the individual motor cars. Both schemes have their advocates. At present, scheme (b) is used almost exclusively for interurban automotive lighting, though a number of trial installations of fixed highway lighting have been made in various parts of the country. It is interesting to note that both methods are undergoing rapid development at present, with the production of more effective light sources and with new schemes for the reduction of glare. What can be expected in the near future?

Lighting from fixed sources had its origin in antiquity, where illumination was undoubtedly provided for special occasions by blazing torches stuck in suitable sockets on buildings or on poles. Later, when better light sources were produced they were treated in the same manner. So we have had, successively, oil lamps, gas lamps, and electric lamps attached to the ends of poles for street lighting, and there has been no analysis of seeing conditions or of whether this or some other scheme would produce best vision. Surprisingly crude methods of design have persisted even up to the present. However, we are now in the midst of a change to more scientific ways. The change was instituted principally by Waldram in England, and is now being carried forward by Cohu in France, by various investigators in Germany and Holland, by the General Electric Company at Nela Park, and in the Electrical Engineering Department at Technology.

It was formerly believed by illuminating engineers that uniform illumination of the street pavement was the criterion of excellence — that if the amount of luminous flux incident on each square meter of pavement was the same, seeing conditions would be ideal. If our pavements belonged to that class of hypothetical surfaces called "perfectly-diffusing," such might be the case; but all actual pavements when viewed at the angles used in practice, appear more nearly in the guise of rippled mirrors. Look down any lighted street and, no matter how carefully the illumination has been made uniform, you will see an irregular bright streak caused by each lamp, with very dark spaces between streaks. The appearance is similar to the bright sun path seen on a body of water in the late afternoon or early morning. These bright streaks have been found very effective in disclosing objects on the pavement — much more effective, in fact, than a perfectly diffusing pavement would be. Even a man in a white palm beach suit will generally appear dark against such a bright streak; and objects of

***A new 4000-lumen incandescent lamp undergoing test in a newly-designed unit at the General Electric illuminating laboratory. Specially constructed for the helmet-shaped luminaire, the lamp has an inch-long filament, enabling the unit to flood more light on the roadway, sidewalks, and shoulders.***

all kinds will usually appear by silhouette against the bright background of the pavement.

If it were economically feasible to compete with nature in her lavish scale of daytime lighting, we would undoubtedly discard the silhouette method of seeing and light both object and pavement to a high level. But on a clear day, each square meter of pavement may receive as much as 1200 watts of radiant power, while in highway lighting a 250-watt lamp is considered sufficient to light seventy meters of pavement ten meters wide, giving but one-third watt per square meter. As long as we are limited in this way, it would seem likely that silhouette would be the most effective method of seeing. If the object is seen against the background of the bright pavement streaks, conditions for detecting its presence are almost ideal. The trouble has been that in most installations the bright areas cover only a very limited part of the pavement, and objects may be quite invisible against the remainder of the pavement which appears black. This is a very dangerous condition and undoubtedly leads to numerous accidents.

*The sodium-vapor units used on this stretch of highway permit motorists to see for half a mile ahead.*

The trouble is being eliminated by improved methods of design which are now under development. The new methods make it possible to predict the size and shape of the bright streak formed on the pavement, for any kind of pavement and for any kind of lamp mounted in any position. Then by using a perspective drawing of the street from the driver's position, the designer can superpose these patterns from the individual luminaires until he obtains a safe condition of brightness over the whole pavement. Thus it is becoming possible for the first time to predetermine exactly how the street will appear to the driver and to design highway lighting on a scientific basis. Much of the work has been done in England. At Technology, a study of visibility was also made by using actual cars operating in traffic under actual highway conditions. To overcome the practical difficulties inherent in the use of actual luminaires to cover a wide range of intensities, mounting heights, and spacings, work was next transferred to the laboratory. A set of 20,000 readings was taken on a scale model of a highway built in the illumination laboratory, the work being done by E. L. Huse and F. M. Neal as a graduate thesis. The further attack on the problem entailed the measurement of actual brightness distributions on various kinds of pavements and the determination of the characteristics of the eye at low levels of illumination. The former investigation was made by K. Y. Cheng and by R. M. Hunt, while the latter was begun by J. P. Conner and R. E. Ganoung and completed by C. C. MacAllister.

Another advance in lighting from fixed sources comes with the introduction of improved electric lamps. The characteristics of some of the tungsten incandescent lamps used in street lighting are given in Table I. It is seen that 20 is approximately the highest value of lumens per watt. Any source that would give more than 20 lumens per watt would be very helpful in highway lighting, where the area to be illuminated is so large and where the economic limitations on wattage are so severe. Accordingly, the advent of the sodium lamp with its output of approximately 60 lumens per watt was hailed as a godsend to highway lighting. The lamp was originally developed by the Philips Works in Holland, whence it was introduced into other European countries and finally appeared in the United States. Several of the earliest installations in this country were made near Boston, so the soft golden light is familiar to most of us. The largest single installation of sodium lamps is on the San Fransico-Oakland Bay Bridge where 1074 lamps are used to light the 15 miles of roadway.

Another recent development is the high-pressure mercury lamp. The ordinary Cooper-Hewitt mercury-vapor lamp has been on the market for many years and gives an overall efficacy of about 10 lumens per watt. Specialists have known for some time that higher values of efficacy could be obtained by raising the vapor pressure from the few millimeters of mercury used in the Cooper-Hewitt lamp to a pressure nearer atmospheric. Not until recently, however, was a successful high-pressure lamp produced in a glass enclosing globe. The 400-watt high-pressure mercury lamp (Table II) gives approximately twice as much luminous flux per watt as is obtainable from the tungsten lamp. The Dutch are again responsible for much of this new development. Their experimental work shows that still higher pressures give a more nearly white light, and values of up to 180 lumens per watt have been obtained in some of their experimental lamps operating at vapor pressures of several hundred atmospheres.

Now turn to the lighting of the highway by means of lamps attached to the individual motor car. The new gaseous-conduction light sources are used for highway lighting from fixed luminaires but are not applicable to automobile headlamps because their large size makes impossible the high degree of control which must be exercised in obtaining a concentrated headlamp beam. The subject of headlamps is almost as dear to the heart of the crackpot inventor as is the subject of perpetual motion, and his inventions are of equal value in the two fields. Present headlamps are carefully

designed and constructed, and experts agree that very little further improvement can be expected from changes in the contour of the reflector or in the lens. When one considers that two 30-watt lamps are used in lighting an area of roadway perhaps 10 meters wide and 100 meters long, while a 100-watt lamp is used to light the ½ square meter of his desk, he realizes that present headlamps must be doing a fairly good job. The big objection to present headlamps is, of course, glare. But if the beam is to be effective it must be almost horizontal; and no matter how carefully the top of the beam is controlled, glare will be experienced under some conditions of pavement irregularities, hills, or heavy car loading. Evidently the solution of the glare menace cannot be found in conventional methods: a radically new approach is required. Several suggestions have been made. The one that is arousing the most interest is the use of polarized light.

Polarized light was largely a laboratory curiosity until the advent of Polaroid, which can be made in large sizes and which gives an effective polarizing medium at reasonable cost. It has been known for some time that certain crystals are very effective in absorbing light that is polarized in one plane and in transmitting light polarized in a plane perpendicular to the former. Some compounds of alkaloids obtained from cinchona bark are of this class. One of them is quinine sulfate periodide, also called herapathite after Herapath who investigated its properties in 1852. The compounds forms very small rod-like crystals, too small to be of any practical use individually. It remained for E. H. Land to develop a feasible way of using these crystals in large numbers. A suspension of the crystals in a liquid matrix is made, the crystals are oriented and the composite material is formed into thin sheets and hardened, after which it can be cemented between glass plates, just as the ordinary colored gelatin filters are cemented for photographic purposes.

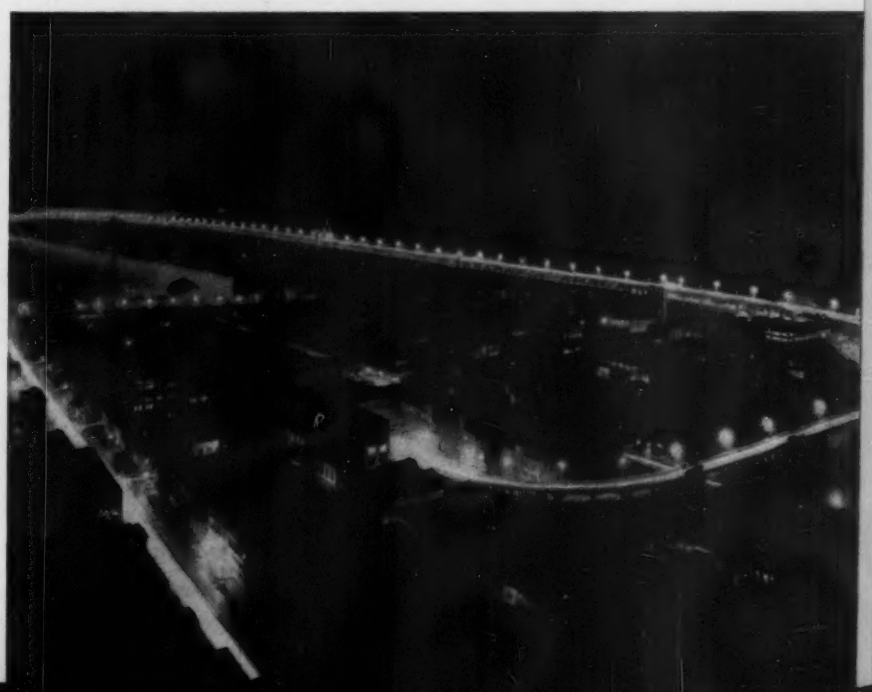
In automotive lighting, polarizing discs are used on the headlamps to produce plane-polarized light, while the driver views the road through another piece of polarizing material which may be incorporated in the windshield, in the sun visor, or in goggles or eye-glasses. In any case, his disc must be so oriented that it absorbs the plane-polarized light emitted by the approaching car. The scheme generally advocated is with all the polarizing discs of all cars adjusted so that they transmit light polarized in a 45° plane from lower left to upper right, when viewed from the driver's position of the car under consideration. Polarized light from your headlamps reflected from polished surfaces will remain polarized and will generally pass through the polarizing windshield with little diminution, so you will be able to see objects by the light of your headlamps as before. Polarized light which has been reflected from diffusing surfaces is almost entirely depolarized but will still be transmitted by your windshield, though with some diminution. But light from the headlamps of the approaching car will be polarized in the plane from upper left to lower right, as viewed from *your* position; and it will be cut out by your polarizing windshield. Thus glare is eliminated.

And there can be no question that glare is actually killed in a very effective manner. The scheme seems so charming that one wonders why he sees no cars equipped with polarizing discs, though Polaroid for photographic and experimental purposes has been available for over a year and polarizing anti-glare glasses are on the market. Further examination of the method, however, reveals an unfortunate number of practical difficulties.

***Safety at night for high-speed traffic on new San Francisco-Oakland Bay bridge is effected by sodium-vapor lamps.***

In the first place, there is the absorption of light by the polarizing medium. The light as produced by the incandescent filament is unpolarized and may be regarded as equivalent to two vector quantities at right angles. In polarizing it, we are deliberately throwing away one of these quantities, and thus with theoretically perfect polarizers 50 per cent of the generated light is wasted. When polarized light strikes diffusing objects it is again "scrambled," and when it subsequently tries to get through the polarized windshield, 50 per cent is again absorbed. With actual materials, the 50 per cent becomes more nearly 65 per cent. The result is that diffusing objects lighted by polarized headlamps and viewed through a polarizing windshield have a brightness of only 10 or 15 per cent of their value if no polarizing media were used. This appears to be a serious objection. It is generally agreed that 32-candlepower lamps without polarizing equipment produce values of brightness which are on the verge of being dangerously low, if indeed they are not definitely below the dangerous level for modern speeds. It would seem, therefore, that the advent of polarized light for motor vehicles should coincide with an increase to approximately 600 watts for the sum of the two headlamps. The change in the electrical system of the car can be imagined. The heating effect on the polarizing equipment and the glare effect for the unprotected pedestrian must be considered also.

(*Continued on page 105*)



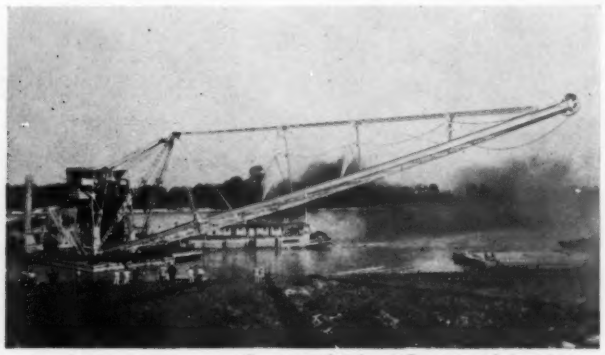
***Another view of the San Francisco-Oakland Bay bridge lighted by sodium-vapor luminaires.***

# Structural Aluminum

## *Aluminum Alloys Give Strength As Well As Lightness to Structures*

IRVING W. WILSON

THE completion last year of a clamshell dredge which can pick up the equivalent of 80 wheelbarrow-loads of dirt in a single bite and swing it onto a levee a block away in less than a minute, has brought to the contractor a machine which greatly increases the scope of his operations. This dredge is equipped with a 240-foot boom and a 6-cubic-yard clamshell bucket. The boom is the longest ever built for this purpose, and its great length was made possible through the use of strong aluminum alloys. The light metal in the form of structural shapes and plate is employed in the outer 150-foot section of the boom to reduce its dead weight 21,000 pounds — a saving equivalent to 14,750 pounds in the bucket. Had light-weight construction not been employed, it would have been necessary to limit the boom length to about 210 feet or the bucket capacity to 4 cubic yards.



*—Courtesy Aluminum Company of America.*

***This 240-foot dredge boom is the longest ever built. It was made possible by constructing the outer 150-foot section of the boom of aluminum shapes and plate.***

Achievements such as this have focused widespread attention on the structural alloys of aluminum. Alloy 17S is the best known of the light alloys because of its extensive use in aircraft construction, and because, until recently, it was the only aluminum alloy possessing sufficient strength to compete with structural steel. Now, as a result of extensive research work and field tests, a number of alloys are available for structural work. The mechanical properties and other characteristics of some of these alloys are given in the table at the end. Each alloy possesses a combination of qualities which makes it especially suitable for certain types of service. For highly stressed parts, 17S-T, 27S-T, or 14S-T may be used, depending on whether the application calls for structural shapes and plate or forgings. Where maximum resistance to severely corrosive conditions is more important than the highest strength, 52S-½H or 53S-T is most satisfactory. Heavy-duty castings are generally made of alloy 220-T4. With the exception of 52S, all the alloys listed in Table I develop their full tensile properties as a result of accurately controlled heat treatment. Alloy 52S is hardened by cold rolling.

To meet the growing demand for structural aluminum, plants equipped with melting furnaces, rolling mills, and heat-treating equipment have been built within the past eight years. The production of structural shapes by rolling is a comparatively new development for aluminum, and considerable experimental work was required before the process was perfected. Prior to this, structural shapes were produced by the extrusion process, but because of the limited capacity of existing extrusion presses and heat-treating equipment, only small sizes and short lengths could be obtained.

The experimental work required before sizable shapes could be produced commercially was mainly of a metallurgical nature. Large shapes require correspondingly large ingots; consequently, one of the first problems was the development of a technique for casting sound, homogeneous ingots weighing from approximately 900 pounds to well over 2,000 pounds, depending on the shape to be rolled. Extrusion billets weigh only a few hundred pounds.

The question of how to roll the large ingots presented another set of problems involving rolling temperatures, reduction per pass, and roll designs. After innumerable trial runs, rolling processes were devised, and angles, channels, tees, and zees are now produced in a range of sizes.

The production of plate for structural purposes was preceded by similar developmental work. Ingots weighing a few hundred pounds have given way to ingots weighing a few thousand pounds. At present, 2,000 pound plates are produced commercially and in some cases this limit may be exceeded by a few hundred pounds.

The availability of large aluminum alloy structural shapes and plates has made practicable the construction of a variety of movable and stationary structures. Giant dippers for power shovels, light-weight floors for overloaded bridges, and emergency bulkheads for movable gate dams are a few of the outstanding examples. In each case, reduction in dead weight results in some economic advantage, such as increased capacity or more desirable operating characteristics. Sometimes the application of light-weight aluminum construction at a strategic point in a large structure actually reduces the initial cost of the structure as a whole.

An example of this is the use of structural aluminum for emergency bulkheads which temporarily dam the water

*—Courtesy Aluminum Company of America.*

***Riveting a built-up aluminum member for the emergency bulkheads at Gallipolis.***

—*Courtesy The Sperryscope.*

***Douglas aircraft under construction at Santa Monica, California. Aluminum alloys are used predominantly in their construction.***

above the gates in navigation dams when repairs and maintenance are necessary. The first set of aluminum bulkheads was made for the new roller-gate dam on the Ohio River at Gallipolis, Ohio. Plans for the Gallipolis dam called for the largest roller gates ever built: 125 feet long, with an effective damming height of 29 feet. In appearance, a roller gate resembles a huge steel cylinder. It fits lengthwise between two concrete piers and is raised by rolling it up a set of inclined tracks built into the piers.

Although there are eight gates in the dam, only one set of emergency bulkheads is required, since it can be shifted from gate to gate as needed. The set consists of seven identical units, each approximately 129 feet long by 4 feet 4 inches high, with a horizontal truss depth of 13 feet. The units fit into vertical slots in the piers and are stacked one above the other, forming a wall 30 feet high.

The customary method of handling bulkheads is by a crane running on a heavy overhead bridge built from pier to pier over the entire dam. Because of the lightness of the aluminum units — 28 tons as compared to 78 tons for structural steel units — they can be handled by a derrick boat, making it possible to substitute a light footbridge for the expensive service bridge and crane. Estimates showed that the construction of a bridge to handle 78-ton units would have been impracticable; consequently, if structural steel bulkheads had been used, it would have been necessary to shorten the gates. Shorter gates meant more piers and more obstruction to the flow of water, ice, and drift. The possibility of using 44-ton nickel-steel units was also considered, but they too would have required a heavy overhead bridge. Thus, by employing structural aluminum bulkheads, the design of the entire dam was simplified and its cost reduced.

Recently, fabrication was started on similar bulkheads for the Winfield dam on the Kanawha River in West Virginia and for the Emsworth dam on the Ohio River at Pittsburgh.

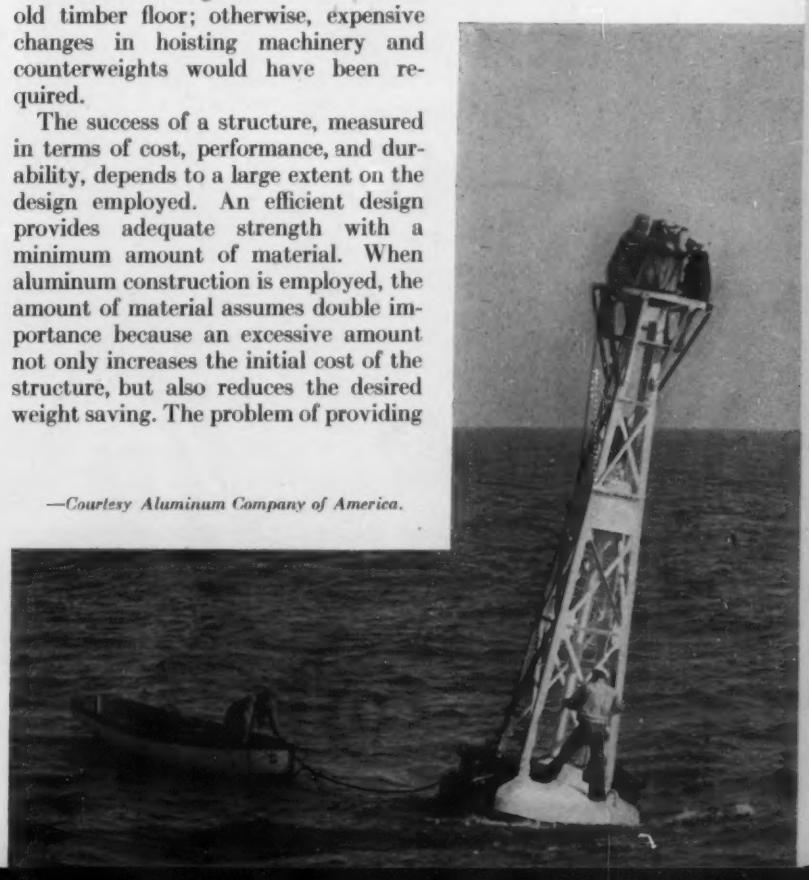
***Light buoy, constructed of aluminum shapes in the Charleston, S. C., harbor.***

The reconstruction, in 1933, of an important highway and electric street-railway bridge in Pittsburgh furnishes another example of economies made possible by the use of structural aluminum. At the time of its reconstruction, the bridge was 51 years old and could not safely handle the steadily increasing traffic. By replacing the old floor system with one made of aluminum alloys, the load carried by the bridge trusses was reduced 750 tons, making the structure safe for anticipated traffic for another 25 years. Since the cost of the 350-ton aluminum floor system was only a fraction of the cost of a new bridge, the taxpayers were saved approximately $1,500,000.

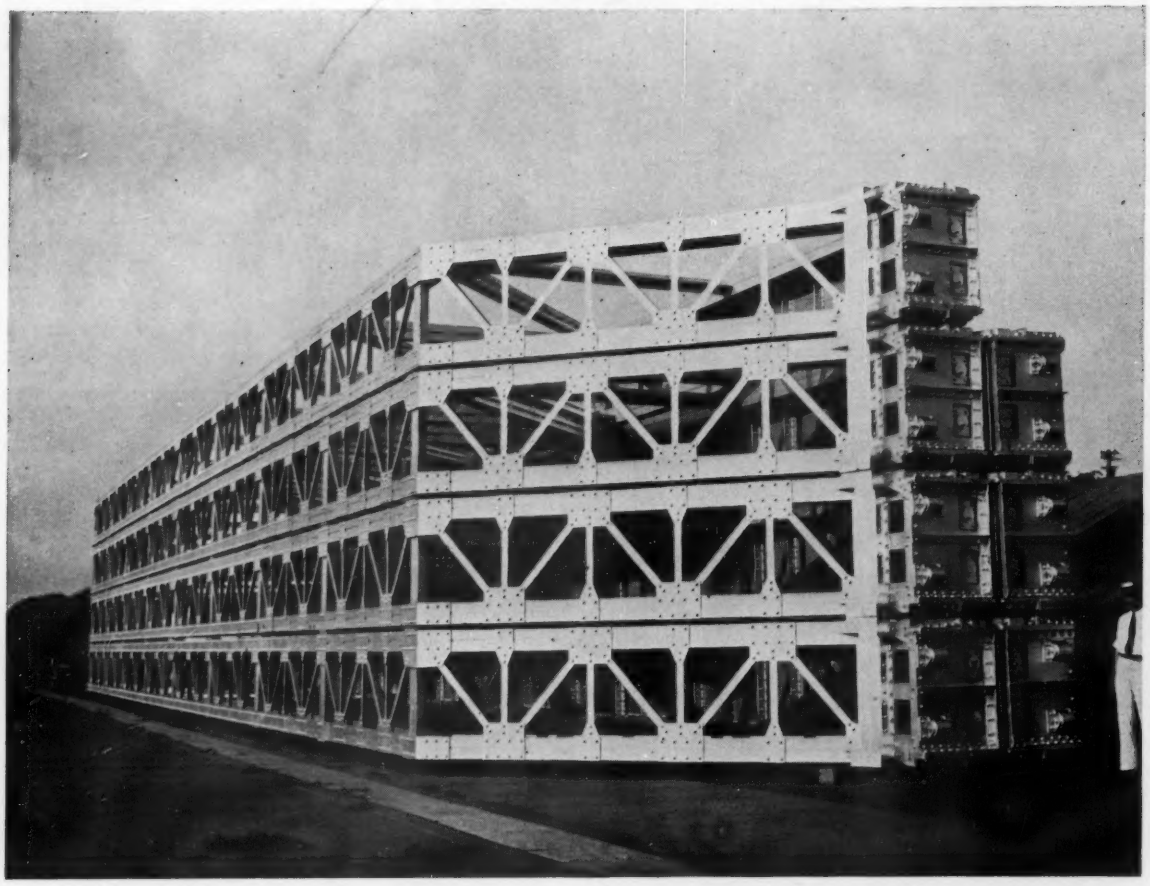
In general, the type of design and method of erection of the aluminum floor did not differ greatly from that which would have been employed if steel construction had been specified. The floor beams and stringers were built up from structural shapes and plate and joined with steel rivets. The roadway is a battledeck type, consisting essentially of aluminum alloy treadplate reinforced with aluminum alloy channels. An asphalt wearing surface was applied to the treadplate. The projections on the plate prevent the asphalt from creeping under the force of heavy vehicles.

Last year, aluminum alloys were employed in the construction of a modern type floor for the Stratford Avenue Bridge on the Boston Post Road, Bridgeport, Connecticut. The new deck is made of aluminum alloy channels laid side by side and joined with rivets through the flanges. The channels were laid with the flanges turned alternately up and down. In the troughs formed by the up-turned channels, asphalt blocks were placed and over the entire surface mineralized asphalt planks were laid to form a wearing surface. Since the bridge is a bascule type, it was important that the new deck weigh no more than the old timber floor; otherwise, expensive changes in hoisting machinery and counterweights would have been required.

The success of a structure, measured in terms of cost, performance, and durability, depends to a large extent on the design employed. An efficient design provides adequate strength with a minimum amount of material. When aluminum construction is employed, the amount of material assumes double importance because an excessive amount not only increases the initial cost of the structure, but also reduces the desired weight saving. The problem of providing



—*Courtesy Aluminum Company of America.*



*—Courtesy Aluminum Company of America*

***Aluminum bulkheads waiting to be installed at the roller-gate dam at Gallipolis, Ohio. Each section is 129 feet long, 13 feet wide, and four feet four inches high, and weighs 28 tons.***

adequate strength is relatively simple in cases where the loads and stresses are determinate, but unfortunately such cases are few. As a result, many designs are based upon assumptions and estimates, and their efficiency depends entirely on the accuracy of the designer's judgment.

In order to make reliable estimates and accurate analyses of loads and stresses, an engineer must be thoroughly familiar with the working requirements of the structure he is designing. To derive full benefit from the construction materials, he must have a complete understanding of their physical properties and fabricating characteristics. In designing aluminum structures, this type of information has been particularly important because of the lack of previous experience with similar structures and the double penalty exacted from the use of excess material.

In general, the fabricating characteristics of structural aluminum, as well as shop practice and erection procedures, are much the same as those for steel. Standard steel-working tools are used for shearing, milling, punching, reaming, and riveting. Joining is usually done with steel rivets driven hot with pneumatic hammers. The practice of cold-driving steel rivets with a squeeze riveter has been used to a limited extent for built-up members. It permits closer clearances and results in exceptionally tight joints. Welding and flame cutting are not permitted because the heat tends to anneal the metal.

In strength and other mechanical properties, the heat-treated aluminum alloys are comparable with structural steel. However, there is considerable difference in some of the physical constants; for example, density, modulus of elasticity, and coefficient of thermal expansion. The density of aluminum alloys varies slightly, depending on the alloying elements employed, but it averages 35 per cent of that for steel. Young's modulus of elasticity is approximately 10,300,000 pounds per square inch, which is also about 35 per cent of the value for structural steel. The coefficient of thermal expansion is slightly more than twice that of steel.

Because of the influence of modulus of elasticity on deflections, it assumes considerable importance in structural designs. An aluminum beam identical in dimensions to a steel beam will weigh about one-third as much, but because of the difference in modulus of elasticity, a given load will deflect the aluminum beam about three times as much as the steel beam. Stiffness also varies directly with the moment of inertia; consequently, a slight increase in the depth of a member insures adequate stiffness and still permits a weight saving of about 50 per cent. There are several other advantages of increased cross-sectional area or bulk which are often overlooked in attempts to save weight. Lack of bulk seriously decreases the stability of local sections and the structure as a whole. To offset this deficiency, an intricate bracing system may be required, which further complicates fabrication difficulties.

As pointed out earlier, an understanding of the properties and characteristics of structural aluminum should be supplemented with complete knowledge of operating requirements, if an engineer is to design an efficient, durable structure. The importance of having this information is well illustrated in the manufacture of aluminum dippers for power shovels used in the strip-mining of coal in the Middle West. Enormous power shovels strip the overburden from the coal beds, and smaller shovels follow and load the coal into trucks or railroad cars. One of the large shovels stands as high as a nine-story building and is equipped with a 32-cubic yard

(*Continued on page 108*)

# Calculating Machines

## *From Abacus to Differential Analyzer in the Attempts to Eliminate Tedious Calculations*

JOHN G. LESCHEN

DR. BUSH'S differential analyzer, one of the Institute's major attractions to-day, is a culmination of a 2000-year development of calculating machines. Its purpose is the same as that of any other calculator — to supersede the human solution of a mathematical problem; for a good machine can eliminate the chances of error which always appear with human calculation, and is also able to solve a problem with much greater rapidity than a mortal can. Moreover, a machine is not bothered by a sense of boredom or by "mental inertia" in routine work, as a man might be. Hence, man finds his calculators most convenient and useful.

Probably the first calculating instrument was the abacus. This, in its most highly developed form, consisted of beads mounted on wires fixed to a frame, for the purpose of simplifying and making operations so concrete that little arithmetic would be required for ordinary calculations. Invented probably by the Semitic races, it was early adopted in India, whence it spread to Europe and China. To-day, it is still considered so important that its use is taught as a regular branch of school work in Russia and Japan; in China, native clerks in banks prefer their equivalent of the abacus, called the *suan-pan*, to Western computing machines.

Little advance was made in calculators until 1617, when John Napier published a description of his numbering rods, later called "Napier's bones." Used for facilitating multiplication, these enjoyed extensive use during the seventeenth century. They consisted of a set of strips marked with the products of the ordinary multiplication table in vertical sequence (Figure 1). Under the "9" in the "nine" strip, for instance, there appeared, in boxes, succeeding multiples of that digit, the tens digits arranged in the upper left-hand corner, and the units digits in the lower right-hand corner of each box. When two numbers were to be multiplied together, the strips bearing at their tops the digits appearing in the multiplicand were chosen, and then placed side by side so that the upper digits were in the same order as in the multiplicand. Thus, if 482799 were to be multiplied by eight, the strips bearing 4,8,2,7,9, and 9 at the top would be placed side by side in that sequence. The eighth horizontal row down, indicated by the multiplier, would then be considered. The product was obtained by adding diagonally, in pairs, the digits in that horizontal row, and placing the sums in the units, tens, hundreds, and so on, places of the desired overall product; the additions would begin on the right and proceed to the left. In this example, "two" would be placed in the product's units place; seven plus two, or nine, in the tens place; six plus seven, or three (from thirteen), in the hundreds; five plus six plus one carried over, or two (from twelve), in the thousands place; and so on. Hence, the product 3862392. Napier's bones, however, do not constitute a real calculating machine, as the term is understood.

| | 4 | 8 | 2 | 7 | 9 | 9 |
|---|---|---|---|---|---|---|
| 2 | 0/8 | 1/6 | 0/4 | 1/4 | 1/8 | 1/8 |
| 3 | 1/2 | 2/4 | 0/6 | 2/1 | 2/7 | 2/7 |
| 4 | 1/6 | 3/2 | 0/8 | 2/8 | 3/6 | 3/6 |
| 5 | 2/0 | 4/0 | 1/0 | 3/5 | 4/5 | 4/5 |
| 6 | 2/4 | 4/8 | 1/2 | 4/2 | 5/4 | 5/4 |
| 7 | 2/8 | 5/6 | 1/4 | 4/9 | 6/3 | 6/3 |
| 8 | 3/2 | 6/4 | 1/6 | 5/6 | 7/2 | 7/2 |
| 9 | 3/6 | 7/2 | 1/8 | 6/3 | 8/1 | 8/1 |

*Figure 1*

Such a device did not appear until 1642, when Blaise Pascal invented his adding machine. He employed figure wheels, each bearing the numbers 0 to 9, as a means of indicating the

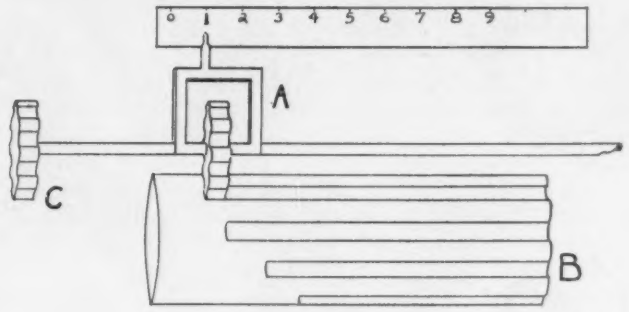



*Figure 2*

sums. Mounted on parallel axes, these figure wheels communicated through a system of gears with corresponding horizontal wheels, which could be advanced one- to nine-tenths of a complete revolution. Each figure wheel rotated in accord with the corresponding horizontal wheel, and caused the next figure wheel to turn through one-tenth of a complete turn whenever the figure wheel changed from nine to zero. Thus, if eight were to be added to seven, the first horizontal wheel would be rotated eight-tenths of a revolution, and then seven-tenths, causing a five to appear under a hole in the box on the corresponding figure wheel; meanwhile, the figure wheel just to the left would register a one. Thus, the sum of a series of numbers was obtained on the figure wheels by successively setting those numbers on the horizontal wheels.

Multiplication is really repeated addition, and consequently could be performed on Pascal's machine. But the process would require so much time and be so tedious that no advantage would be gained by using the machine. If 8642 were to be multiplied by 43, for instance, the following long series of additions would be necessary: (8642 + 8642 + 8642) + (86420 + 86420 + 86420 + 86420).

It was Gottfried Wilhelm von Leibnitz who introduced in 1694 a machine designed specifically for multiplying, utilizing the principle of rapidly repeated addition. In his device, ths multiplicand was set on a sliding portion movable by stepe into positions corresponding to units, tens, hundreds, and so on. Figure wheels on the fixed portion of the machine regis-

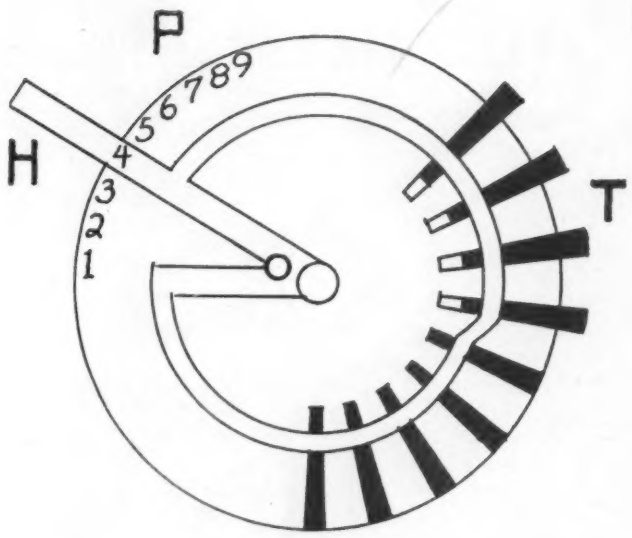



*Figure 3*

tered the results of addition rapidly repeated to up nine times the multiplicand. The important feature of the machine was the stepped wheel (Figure 2), a cylindrical drum which had on its outer surface nine teeth of increasing length. In the position shown, only one of the teeth on *B* can engage with those on wheel *A*. If, however, *A* is moved to the right, say to position 5, five cogs on *B* would mesh with those on *A*. Thus, one turn of *B* will register a 1 or a 5 on the counter.

Still in extensive use, the Leibnitz wheel appeared in many subsequent machines, among which was the first calculator that was commercially successful — that of Charles X. Thomas of Alsace. Invented in 1820, the mechanism may be divided into three parts, concerned with setting, counting, and recording. It could perform operations on any number (up to 999,999) which was set by adjusting six pointers, each corresponding to part *A* in figure 2, on a fixed cover-plate. Under each pointer was a Leibnitz wheel, which, with *A*, could control by means of a connection through *C* the figure appearing on its results figure wheel. The result as well as the multiplier appeared on a hinged cover plate. If 5108 were to be multiplied by 257 (Figure 5), as an example, all the figure wheels would first be set to zero; the hinged plate would be lifted, moved to the extreme left position, and set down again; the number 5108 would be set on the pointers; and a lever in the upper left hand corner of the fixed plate would be set to "Addition or Multiplication," instead of "Subtraction or Division," to prepare the machine. Then the driving crank would be turned twice, causing all the Leibnitz wheels to make two revolutions; the hinged plate lifted and moved one place to the right; and again lowered. The handle would be turned five times, the plate moved another step to the right, and the handle turned seven times. The product 1,312,756 would appear on the top row of figure wheels, and the multiplier just below. As may be seen, this operation is merely repeated addition.

About 1875,W. T. Odhner designed a machine in which the Leibnitz stepped wheel was replaced by a wheel from whose rim a variable number of teeth (1 to 9) protruded. The new wheels could fit very closely together, so that the machine could be made more compact. Each wheel had a setting lever *H* (Figure 3), which extended through the cylindrical part of the cover plate *P*. By rotating *H* clockwise, an increasing number (1 to 9) of teeth *T* could be protruded from the wheel, so that, when the wheel was turned as a whole, the teeth would engage with the counter as they passed it. The wheel would be rotated clockwise for addition or multiplication and in the opposite direction for subtraction or division, instead of relying on a shift of gears for a change of operations, as did the Thomas machine. Otherwise, except for the carriage's being moved by the pressing of levers, the principle was essentially the same as that of Thomas's device, and it, too, is still used to-day.

Another general type of adding machine employed to-day is the rocking segment (Figure 4). When the segment *S* is turning clockwise, it is in gear with the counter *C*, whereas, when it turns back again, *C* is disengaged. The amount of turning of *S* is regulated by depressing one of the keys *K* (number 7 in the diagram).

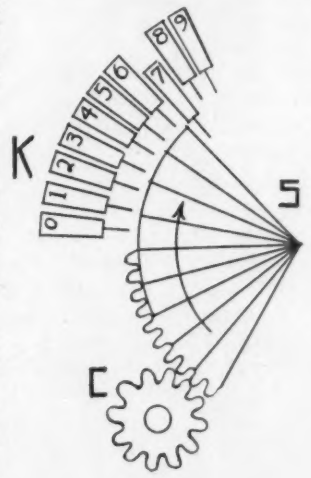



*Figure 4*

Subtraction is usually accomplished by one of two methods. The operator could add the number which, when added to the subtrahend, would set all the figure wheels equal to zero; to subtract 000742, for instance, he would add 999258. Or, mechanically, he could change the direction of rotation of part of a subtraction machine by throwing a switch, instead of reversing the motion of the whole machine by turning the crank in the opposite direction, since this procedure would lead to difficulties.

In 1887 Leon Bollee furnished the world with its first machine which would multiply directly, thus avoiding the longer, repeated addition process. The distinguishing feature of the new machine was an automatic multiplication table in the form of a series of tongued plates. Each digit which was used as a multiplier possessed nine pairs of tongues of variable lengths, the members of each pair corresponding to tens and

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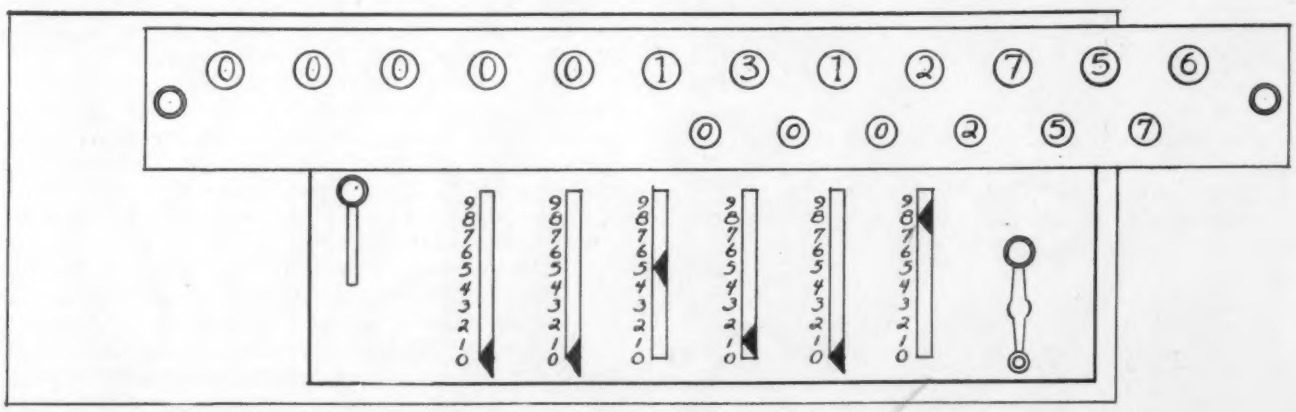



*Figure 5*

# Propeller Stresses

## *A Research Program Provides for Measuring Aircraft Propeller Stresses in Flight*

*Presented at the Structural Problems in Aircraft Design Session, Fifth Annual Meeting, I. Ae. S. January 27, 1937*

ALFRED V. DE FOREST

AS the result of several years of research, Hamilton Standard Propellers has arrived at a practical solution of the difficult problem of measuring aircraft propeller stresses in flight, which should have useful applications in other fields. The obvious difficulties to be overcome in continuously recording these stresses under all conditions have required the development of equipment and technique which should be easy to apply in other situations where space and weight are not at such a premium.

In the design of any engineering structure the first step is necessarily the establishment of the loads which the structure is to carry. Frequently, as in the case of bridges, buildings, ships, dams, and machinery where the new design does not depart radically from old and well-tried models, the structural elements are not calculated, but assumed by interpolation or extrapolation from the previous art. In this case the loads are not calculated as such, but are in general known to be below a certain limit of safety. How far below is seldom taken into consideration, for in most cases it is more economical to use a large factor of safety than to carry out a sufficiently careful study to eliminate the under-stressed material.

Where weight carries a penalty, as in rapidly moving machine parts and in airplane structures in general, it is important to learn as much as possible of the loading conditions so that the design may result in giving adequate strength to all parts with a minimum of parasitic weight. In no case is this more important than in the airplane propeller, where structural failure is inordinately expensive, and where excess weight not only is a burden to carry, but decreases the aerodynamic efficiency of the propeller blade.

When, about 1923, aluminum alloy blades came into use, it was soon realized that the blade was acting as a freely vibrating body, with stresses dependent on many different types of resonant vibration, and limited by the internal and external damping of the vibrating system.

Experience covering many types of engines, planes, and propellers, enabled the designers to meet various conditions, but without separating the various stress-raising types of vibration.

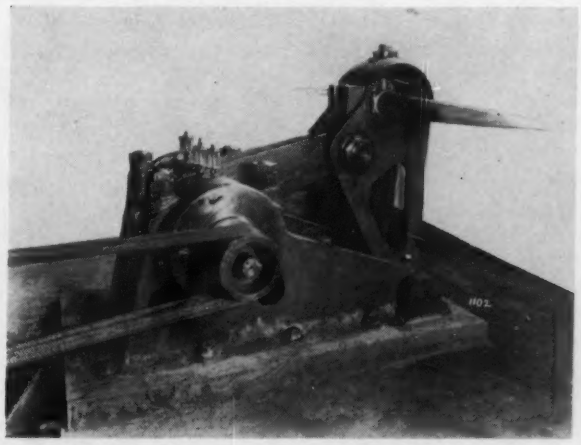
The most serious failures in propeller blades are those which occur close to the hub, for in this case the unbalance is usually so great as to tear the engine out of its mountings. The design of the shank and its attachment to the hub must, therefore, be especially considered. In order to study this portion of the blade, and to some extent the hub also, a heavy vibrating machine was built by Hamilton in 1930 (Fig. 1). This machine applies forced vibrations of $\frac{3}{8}$ inch amplitude at a frequency of 1750 per minute.

To compare the strength of various designs, a propeller of a type with a favorable service record is loaded with weights distributed along the blade, so adjusted that the natural period of the blade is not in resonance with the motion of the machine, but sufficient to break the blade in about 1,000,000 cycles. Other designs are then compared with this one and weaknesses at particular points may be corrected. As the stresses imposed are not the same as in service, due particularly to the absence of centrifugal loads, this test is necessarily only a guide and must be supplemented by regular full-power engine tests. Obviously, the use of this machine, as well as other accelerated laboratory tests, can only be made complete by an actual knowledge of propeller stresses in service.

A research program was started in 1933 with two major objectives: first, means for measuring the important service stresses, and second, means for reproducing these stresses in the laboratory. The first objective seems now to have been successfully reached, and it is felt that the steps taken and the results obtained may be of interest to others dealing with similar problems.

The constant loads on a propeller, those due to centrifugal force and air pressure, are possible of calculation and the strength of a propeller, subject to such loads, may be readily measured by a whirling test. Such tests, even at two or three times the designed power input, do not reproduce the failures which are met with in service.

The dynamic loads may be divided into two classes. First, those due to the varying air loads, obstructions of the slip stream, turbulence at the tips, etc. which would be present even with constant torque and no vibratory motion of the hub, and second, the forces due to torque variations and the varying motion of the centre of the hub in space. None of these dynamic forces cause important stresses except where their periods lead to one or more types of resonant vibration. It is well known that in a truly elastic body subject to resonant excitation, the stresses are rapidly built up to the elastic limit of the system, and are only limited by the external damping forces.



*—All illustrations courtesy Journal of the Aeronautical Sciences.*

***Fig. 1. Forced vibration test machine.***

All metals have a certain amount of internal damping; in other words, are not truly elastic, and also there is a comparatively large loss of energy at fitted joints. Where the connections are simple, as in the fixed pitch propeller, there is less damping than in the variable pitch with its greater number of moving parts. The external damping due to the surrounding air is more important than the internal damping, but cannot be calculated without accurate knowledge of the amplitude

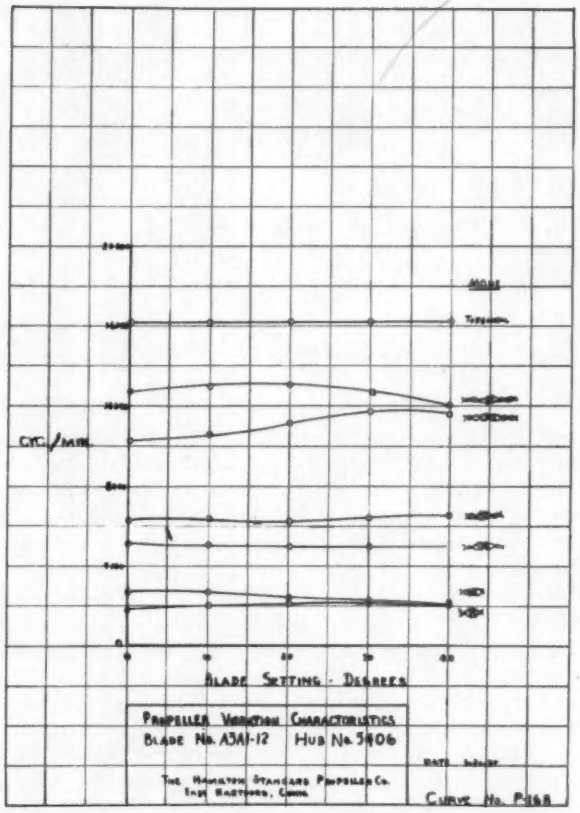



*Fig. 2. Resonant vibration characteristics of a propeller with rotating flywheel excitation.*

frequency of the vibration. With this knowledge the effect of both internal and external damping can be properly investigated.

The exciting forces, apart from the aerodynamic ones already mentioned, are those resulting from the power plant and propeller combination. A complete list of all these effects is unnecessary, but the most obvious ones are listed for purposes of illustration.

(1) Torque variations in the driving force, especially when resonance occurs between a natural period of the crank shaft plus propeller and the power impulses.

(2) Fore and aft vibration of the propeller hub in space, either with or without a corresponding motion of the engine as a whole.

(3) Motion of the centre of the propeller hub in the vertical plane, such as produced by the centre of rotation not coinciding with the centre of gravity.

(4) A pitching or yawing motion of the propeller hub in space due to reciprocating and rotational unbalance.

A simple method of producing the various types of vibration which can produce resonance in the propeller was introduced in 1933. The blades, mounted in their hub, were suspended from an elastic sling and an air motor with an out-of-balance flywheel was attached to the hub. When the excitation is in resonance with any natural period, vibrations are set up which can easily be observed, their periods being measured from the rotational speed of the motor. The stress distribution under different modes of vibration can also be either calculated or measured. Also, stresses can be set up sufficient to break the propeller blade by fatigue at about the same locations and with the same appearance as those failures occurring in service, and furthermore, this stress could be set up by the expenditure of very little power.

The question then appeared to be, "Why do not all propellers fail, as some type of vibration must be in resonance during some portion of the engine's range?" To get any answer, it was necessary to find out what periods of vibration and what limiting stresses are excited during service condition.

From studies with the rotating flywheel, three general types of vibration can readily be identified. First: with the hub moving up and down with axis parallel, and blades flapping in phase with each other as do the wings of a flying bird. Second: the out of phase vibration where one blade is moving in the opposite direction from the other, the shape of the blades being the same in each case. The fundamental form of both types of vibration shows no blade element stationary in space, but at higher speeds, 1, 2, 3, or more stationary lines can be identified, corresponding to the first, second, and third harmonics. The positions of these lines of no motion are easily located with blades set at 0 pitch by the old system of sprinkling light powder, for instance, sawdust, on the vibrating blade, showing nodes as in the well-known Chladni's figures on vibrating plates. The periods of the different forms of vibration are shown in Figure 2. Third: torsional vibration of the blade about its longitudinal axis takes place at high frequency, about 20,000 cycles per minute, but the stresses associated with this form are probably low.

From the nomenclature applied to the vibration of wires fixed at both ends, the positions of no motion have been termed nodes, but it is to be particularly observed that the "node" nearest the end of the blade is not a position of zero stress as are the other true nodes where harmonics are present. In fact it is in reality close to a position of maximum stress.

The rotating flywheel exciter is a most useful tool for the laboratory study of propeller vibration periods, but the proper correlation with test stand and flight conditions is necessary to utilize the full possibilities of the test as a method for stress analysis. To do this requires either a knowledge of the modes of vibration in space of both the engine and the propeller, or a measurement of the local stress at each point of blade.

The measurement of local stresses seemed to be the easier problem, and a scratch recording strain gauge was developed which gave the actual strain over a 2 inch length, and was light enough to operate at high accelerations encountered near the propeller tip. This gauge was used on the propeller vibrated by the rotating flywheel and furnished good measurements from which to correct stresses calculated from the measured amplitude and mode of vibration. Figure 3 shows the scratch gauge and Figure 4 gives the stress distribution along the blade at various resonant frequencies. The curves in Figure 5 give stresses on the test stand at various speeds. Examination of the scratch record shows more than a simple harmonic motion in nearly every case, so a direct relation between Figures 4 and 5 is not possible. The scratch records give only maxima, and do not give frequency, wave form, or phase relation between different stations. Also, the scratch record does not cover a sufficient length of time to allow resonant vibration, to be recorded with certainty, unless some positive information is available as to when the record is to be started.

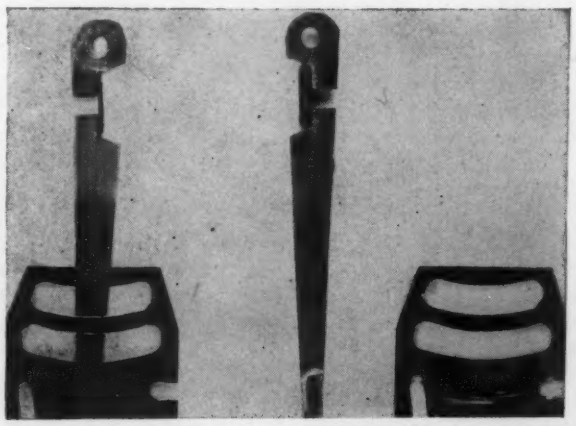


*Fig. 3. deForest scratch gauge. Two-inch gauge length.*

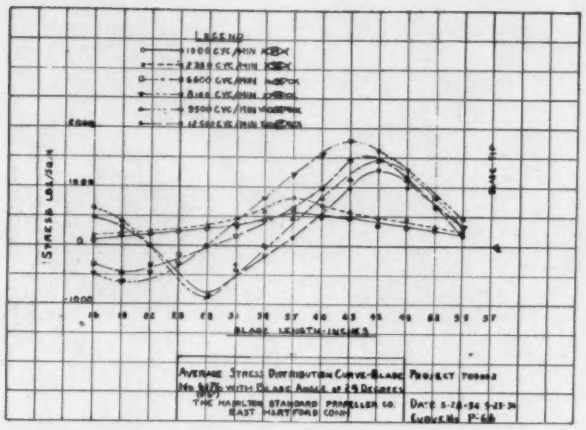



*Fig. 4. Stress distribution along the length of a blade under various resonant conditions. Scratch gauge results.*

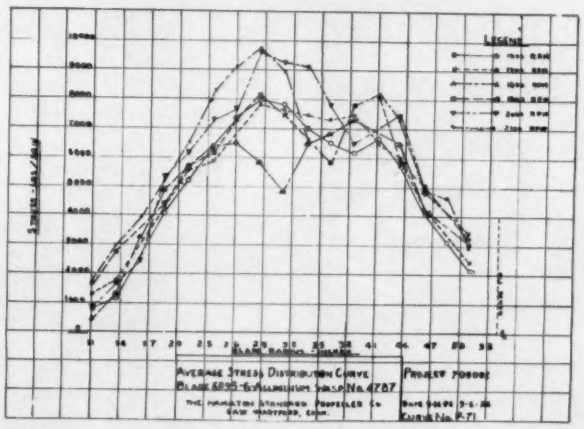



*Fig. 5. Stresses in blade at different speeds on test stand. Wasp engine.*

Although stresses along the whole length of the blade for several hundred vibrations had been measured, there was no positive knowledge that under some other condition resonance would not occur. Also, even more important, there was no basis for identifying the particular engine vibration which excited the propeller under different speeds and power outputs.

What seemed needed was a continuous indication and record of local stress, acceleration, or displacement, with phase relations between the local motions and the cylinder explosions.

It is needless to elaborate on all the attempts to reach this goal, but many lessons were learned through failure, and are mentioned because of the general interest in vibration and stress measurement.

A series of tests were run on a direct optical method using small concave mirrors mounted at different points on the blades, each tracing a small circle on a screen in line with the centre line of the shaft. The resulting patterns were too complex for ready analysis.

Acoustic pick-ups were used, in conjunction with a General Electric sound analyzer; but this offered no solution of the local stress distribution.

Much work was carried on with various electrical strain gauges or accelerometers to be attached directly to the blades, the resulting indications carried through collector rings to an amplifier and oscillograph. A magnetic pick-up measuring rate of motion was built of sufficiently small dimensions to try out, and good records were made on the vibrator but the results require integration to be a measure of stress, and with complicated wave forms this is difficult if not impractical by ordinary methods. However, direct stress measurement is preferable to results derived from acceleration measurements, as it cannot be assumed that the engine vibration as a whole is negligible.

Another accelerometer was also tried, consisting of the device commonly used for producing sound vibrations directly in the bones of the head. This unit, after calibration, would work for a static vibration test, but was unsuitable for the high centrifugal loading of rotating propellers. The electrical system is closely akin to the electric torsiograph and requires an integrating circuit to give results in terms of stress. Accelerometers of the carbon-disc type were tried, as were also small granular carbon microphones, but while frequency and

(*Continued on page 101*)

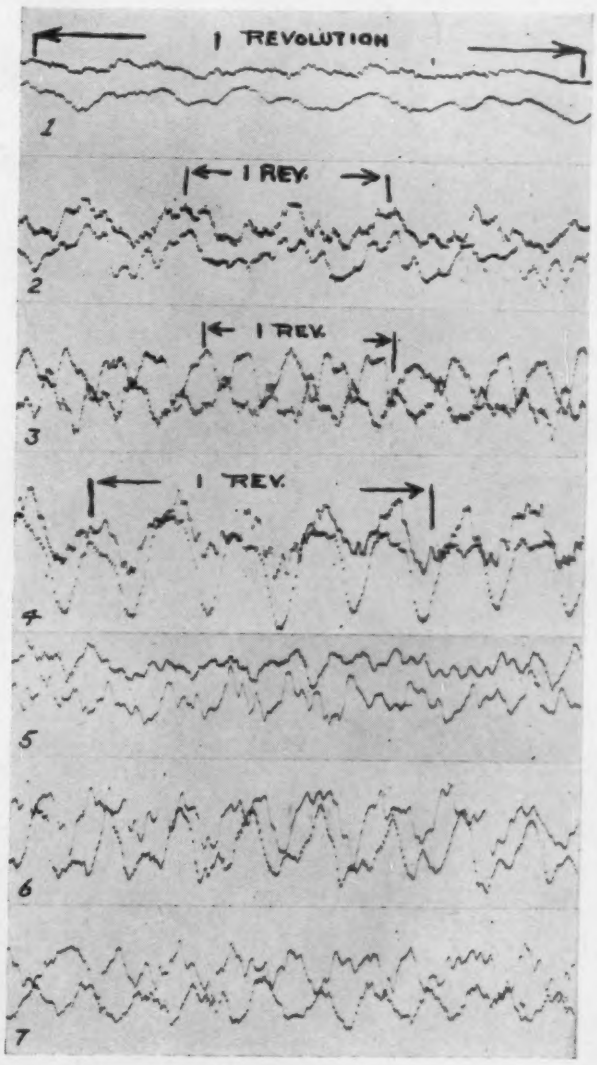
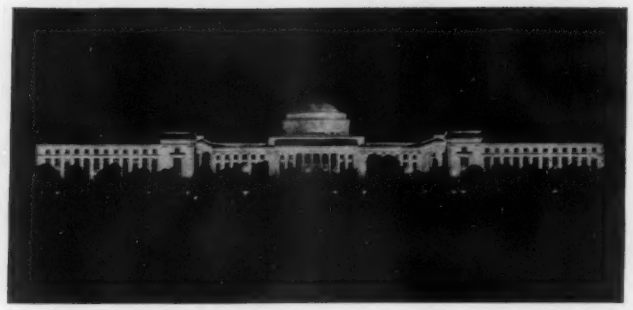



*Fig. 6*

1. *1000 r.p.m. No resonance.*
2. *1300 r.p.m. Test stand. In phase vibration. Stress ±3300 lbs. per sq. in.*
3. *1400 r.p.m. Test stand. Out of phase vibration. Resonance with power impulses. Stress =5000 lbs. per sq. in.*
4. *1650 r.p.m. Test stand. In phase vibration. Resonance with power impulses. Stress =6750 lbs. per sq. in.*
5. *1900 r.p.m. Air. Take off. No resonance. Stress ±2500 lbs. per sq. in.*
6. *1600 r.p.m. Air. Second harmonic in phase type vibration. Resonance with power impulses. Stress ±5000 lbs. per sq. in.*
7. *2000 r.p.m. Air. Out of phase type vibration. Resonance with power impulses.*

# THE TECH ENGINEERING NEWS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# EDITORIALS

## *EMPLOYMENT PROSPECTS*

TECHNOLOGY students, and especially those of the class of 1937, have good reason to be cheerful over their chances of employment after graduation. According to a report of the Bureau of Industrial Service, Inc., it is stated that employment prospects this year are only slightly less auspicious than those of 1929, and appreciably better than those of 1936.

These conclusions were not reached through idle conjecture, but rather are based upon the results of a number of questionnaires returned by many leading colleges and universities. Encouraging also to Institute students is the fact that the number of engineering and business-administration graduates is high on the list of placed men. It has been found, too, that the larger corporations have been leading in the number of prospective jobs.

"More than half of the June graduates of 185 institutions replying to the questionnaire are expected to be on payrolls before the end of the summer," reported Mr. J. R. Ridgeway, president of Investors Syndicate, Minneapolis, who further said that twenty-eight universities expect more than 90 per cent of their graduates to gain employment.

Scholarship was ranked as the leading qualification by most executives. This augers favorably for Institute graduates, who have always been noted for their achievements in this respect. Campus activity and personality were also ranked high among the desired qualifications.

A few statistics from the bulk of the replies are as follows: 51.4 per cent of the replies ranked scholarship as the highest prerequisite, while 19.7 per cent of the institutions rated personality as highest, and five per cent chose character. Hence, after its excellent record for placement in leaner years, it seems logical to believe that the Institute may reach a new high in placements this year, a possibility that promises well for future plans of a "Greater Technology."

## *CONTAINERS*

THE old saying that "good things come in small packages" is being adopted as good sales psychology. The "single-use,"small container, a recent brain-child of modern industry, is proving to be a very definite link between mass production on one hand, and retail trade in small quantities on the other. Consider the case of a small dealer in paints. Instead of buying

large quantities of different colored paints as he formerly had to do in order to satisfy the demands of a number of customers, and then having these numerous cans occupy in no small measure the shelve-space of his shop, he may now buy a much smaller amount of uncolored or white paint put up in the usual manner. Then, to satisfy the demand for colors, he may buy colored pigment in small, inexpensive tubes which the customer uses to color his own paint. This procedure saves the dealer almost six-sevenths the space previously usurped by the old method, and by keeping a wide variety of the tubed pigments, he can serve many more customers.

The use of small containers has spread far beyond the paint industry. Cans for beer, with a special "keglined" treatment, were able to make war on the old style bottles, and have nearly defeated them. Paper, pulp, and other containers for liquids have had less success, but a non-refillable, transparent container for motor oils, which allows the buyer to see the material he is purchasing, and which may be burnt up when empty, is making definite progress. Soluble coffee, as well as hair tonic, powders, tooth paste, and even a de-hydrated "cocktail" is put up in attractive tin tubes. The practice of utilizing the smaller container method of retailing a product has unlimited possibilities, and is a positive psychological stimulus toward increasing sales. The containers themselves are usually inexpensive; they may be made very attractive. Most of the containers are built in such a way that they may not be used a second time. This protects both the manufacturer from a substitution of a cheaper brand of goods, and the customer from getting something he has not bargained for. As a result, everyone seems to be pleased, and, hence, we can expect a marked increase in the applications of the small, single-use container.

## *POLICY*

DURING the past four years THE TECH ENGINEERING NEWS has won repeated recognition of its excellence as an undergraduate scientific and engineering publication. Last year the magazine won permanent possession of the Yale Cup after having won it for three consecutive times during the first three years that it was offered for competition. This year, too, the publication has won favorable comments from the officers of the Engineering College Magazines Associated. Reprints of its articles have frequently appeared in the magazine *Science Digest*, and such newspapers as the *New York Times* and the *Boston Transcript* have used material from its articles.

It is, therefore, in line with the publication's policy of maintaining a high standard, that this issue should bear a new, and, we hope, more attractive and versatile cover. This cover was designed by one of Technology's own students in Architecture, Eugene E. Crawford, '41. In the same vein, likewise, is the expansion of the publication into an issue this month that is four pages larger than the previous issues.

It has been suggested that the magazine should contain some medium for the expressions and comments of our readers. Therefore, these pages will henceforward contain just such a column if the interest of our readers justifies its initiation.

## *CONTEST*

THE TECH ENGINEERING NEWS will sponsor a monthly contest for pictures to be used on its cover. For the October contest the picture most be taken with Leica camera. From among the pictures entered, THE TECH ENGINEERING NEWS will select the best, which will then be sent to the E. Leitz, Inc., manufacturer of the Leica cameras, for the final judging. Arrangements are underway whereby, after the October contest, competition will be open to pictures taken by the other makes of cameras.

The subjects should be of engineering, scientific, or architectural interest. All entries must be glossy prints, at least eight by ten inches in size, with the long edge of the picture vertical. The closing date for each month's competition will be announced in the fall. All entries for the October competition must be in THE TECH ENGINEERING NEWS office by September 1.

The winning photographer will receive, besides the recognition of having his photograph published, a term subscription to THE TECH ENGINEERING NEWS and free copies of the issue in which his photograph appears. The issue will also carry a biographical sketch of the winner.

Everyone concerned with Technology is eligible to enter whether a student or not. Any number of photographs may be entered in a single contest, and the same picture may be entered in any number of the contests.

## *ANNOUNCEMENT*

THE Managing Board is pleased to announce the following promotions: Lester Lees, '40, Jack H. Schaum, '40, and Eugene S. West, '40, to the positions of Assistant Editors; Norman L. Laschever, '40, John G. Leschen, '40, and James S. Rumsey, '40, to the positions of Assistant Managing Editors; James L. Baird, '40, and Harry N. Cottle, '40, to the positions of Assistant Circulation Managers; Samuel P. Card, '40, to the position of Assistant Advertising Manager; Oliver H. Fulton, '40, to the position of Assistant Publicity Manager; Gordon A. Fairbairn, '40, and James G. Magee, '40, to the positions of Assistant Treasurers; and Eugene E. Crawford, '41, to the position of Assistant Art Editor.

# RESEARCH IN REVIEW

## COURSE II — Testing Materials Laboratory

IN modern structures in the civil and mechanical fields in which vibratory and reversed loading are encountered, certain troublesome failures have occurred after a period of service, despite the usual design precautions, and contradictory to static laboratory tests. The fractures generally appeared as a square crystalline break across the loaded piece with none of the evidences of ductility, or "softness" accompanying a static test of the same piece, and since this type of failure appears radically different from the static failure and occurs only after a considerable period of service loading, it has been identified by the name "fatigue failure." Early explanations attributed the difficulty to a "crystallization" of the metal, on account of the appearance of the fracture, and even after thirty years of more enlightened investigation it seems that "crystallization" is still strong in the mind of the mechanic.

Even before the fundamental mechanism of the fatigue failure was understood, it was recognized that laboratory tests involving vibratory loading were necessary to simulate service conditions and to furnish data for design. On this basis designers have called for, and testing engineers have furnished a large amount of statistical data relating the stress imposed on a given material to the number of vibrations, or cycles of reversal of loading, which it will withstand without fracture. Thus, in common low carbon steel, it has been shown that a stress in the vicinity of one-half of the ultimate tensile strength of the metal will cause a fatigue failure in less than ten million cycles of stress reversal, while a stress of slightly less than this amount can be applied practically an infinite number of times.

Unfortunately this simple relation of safe stress, or "endurance limit," to ultimate strength does not hold for other materials than ordinary steel, and with the increasing use of high alloy steels and of light weight and non-corrosive metals the amount of statistical data on fatigue has increased enormously. Further complications have developed because of the influence of such factors as surface finish, alloying of the surface, cold working, size of the test piece, and to a lesser extent the speed of reversal of the load.

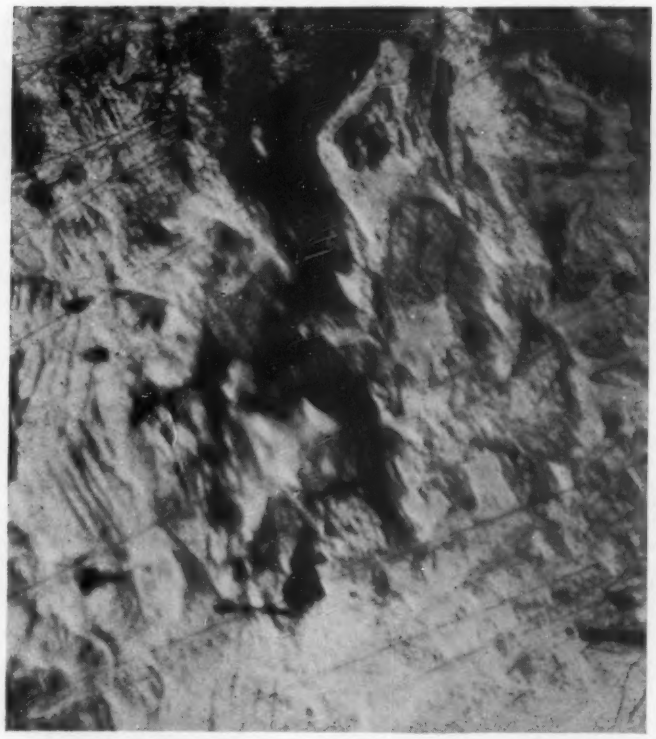
With this fast increase in the amount of statistical data to be interpreted there has arisen a need for a more fundamental attack on the general nature of the fatigue phenomenon — in other words, the development of a theory to supersede the "crystallization" myth. It was long ago noticed that the final failure was preceded by a minute and often invisible crack which worked progressively into the piece until the remaining area was no longer sufficient to carry the load, and a square brittle fracture occurred. While many investigators have examined the metal in the region of the crack after the failure, a satisfactory examination can only be made while the crack is progressing under the action of the reversing loading, utilizing the microscope for the purpose.

The Testing Materials Research Laboratory of the Department of Mechanical Engineering has taken up the work carried on by a few investigators in the last fifteen years, and has constructed, under the direction of Robert W. Vose, a special machine for producing and studying the fatigue failure. In this machine a belt driven shaft carries a variable throw eccentric with a ball bearing strap, while a cantilever beam made of the material under investigation is held by spring pressure against the outer race of the ball bearing and thus receives the motion of the eccentric. By suitable adjustment of this motion a changing stress of definite distribution may be imposed on the beam through any number of cycles as registered on a revolution counter attached to the driving shaft. After a period of operation ranging from a hundred thousand to several million cycles, depending on the magnitude of the imposed stress, a typical fatigue crack developes at the most highly stressed location in the beam, and progresses slowly through the material.

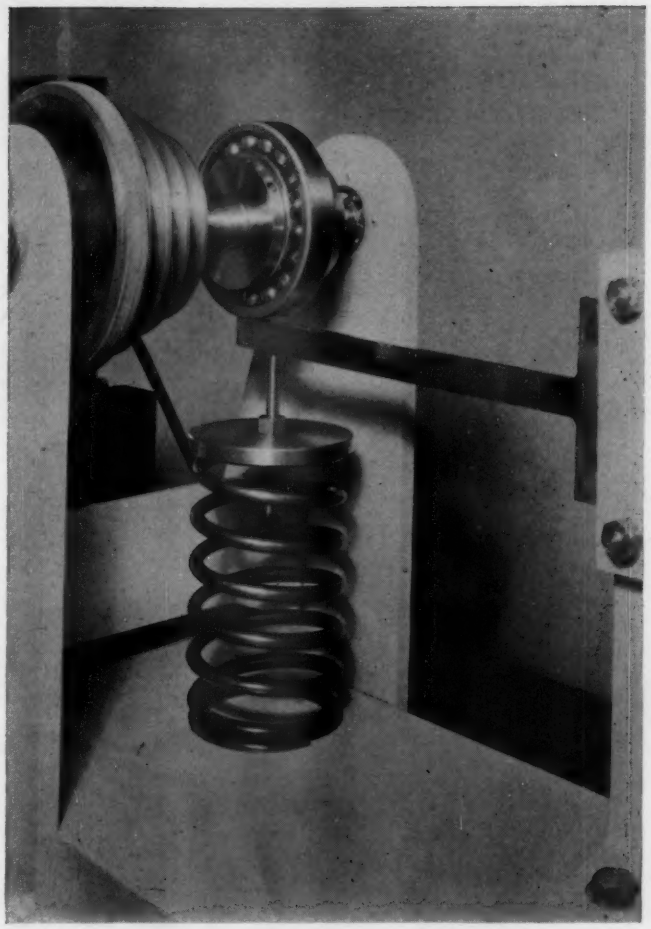
By focusing a metallurgical microscope on the previously polished surface of the specimen the action of the high local stresses in the vicinity of the crack, and the plastic yielding and final fracture of the individual grains of the metal, may be observed. A further means of investigation is the use of a "Newton's rings" interferometer, introduced by the Institute staff, by which the surface deformations may be accurately measured and utilized in the analysis of the stress distribution in the affected region.

Through the use of this apparatus it has been possible to demonstrate that the mechanism of fatigue failure is much like that encountered in breaking off a piece of ductile wire by repeated sharp bending. The repeated plastic flow, first in one direction and then in the reverse direction, which is forced into the wire is also present in a minute area at the root of the fatigue crack, and is caused by the stress concentration accompanying all sharp notches. As is perfectly evident in the breaking of the wire, the material which withstands a few reversals of flow without harm will eventually harden and crack under this action, and thus cause the progression of the crack.

Up to the present time none of the investigations of the type now under way have passed beyond the stage of a demonstration of the action involved, but with modern statistical information on the relative fatigue resistance of various materials it is hoped that the basic factors involved may be discovered and possibly evaluated. Damping capacity (lack of "ring" in a metal when struck with a hammer), work-hardening ability, crystalline structure, and initial stress, are some of



*Photograph of Fatigue crack taken with apparatus.*



*Apparatus used to propagate a crack.*

the known influencing factors which need such demonstrative investigation.

## COURSE V — Chemistry

NOT long ago there was described in this place the new program of the Institute in cellulose chemistry. Also in the field of natural products is the work of Dr. W. F. Ross, a newcomer to the Institute. He was formerly at the Rockefeller Institute in New York City, working with Dr. M. Bergmann on the relation of synthetic peptides to the proteolytic enzymes.

The proteolytic enzymes are natural catalysts for breaking up proteins, the nitrogen containing constituents of the diet, into their components, the amino acids. By the proper choice of amino acids in synthetic polypeptides, it has been possible to correlate enzyme activity with specific properties of the peptide linkage involved; it was with this work that Dr. Ross was associated at the Rockefeller Institute. Amino acids, which contain in the same molecule both basic and acidic groups, may be coupled to form peptides by the intermolecular loss of water from these groups. A peptide linkage is thus formed. Such bonds hold together the amino acids in proteins, and are hydrolyzed by the proteolytic enzymes.

During digestion proteins are attacked first by pepsin within the stomach and are then completely hydrolyzed to amino acids by the pancreatic enzymes in the intestine. The pancreatic enzymes have been differentiated as follows: dipeptidase, which splits only dipeptides; carboxypeptidase, which attacks the peptide linkage at the carboxyl end of the chain; aminopeptidase, which splits at the amino end; and trypsin. Pepsin and trypsin were named proteinases because their action appeared to be restricted to the high molecular proteins. With the discovery by Bergmann and Ross that a simple peptide of lysine, a di-amino, mono-carboxylic acid, is split by trypsin, it became clear that the proteinases split normal peptide linkages in low molecular peptides and are therefore true peptidases. Appropriate side chains of the amino acids forming the peptide linkage, as the free amino group in their synthetic substrate, a-benzoyl-glycyl-lysine amide, make the linkage available for proteinase action.

Here at M. I. T. the relation of the highly colored porphyrins to proteins is being studied by Dr. Ross. In hemoglobin, protoporphyrin is associated through an atom of iron to globin, a protein of molecular weight 67,000. Hemoglobin through this linkage is enabled to combine reversibly with oxygen. The nature of the point within the protein at which combination occurs is not known; it is this which is the subject of especial attention. There is also being investigated the possibility that chlorophyll, a modified porphyrin-magnesium compound, may also be associated with a protein in nature to form a substance similar in composition to hemoglobin.

## COURSE XVI — Meteorology

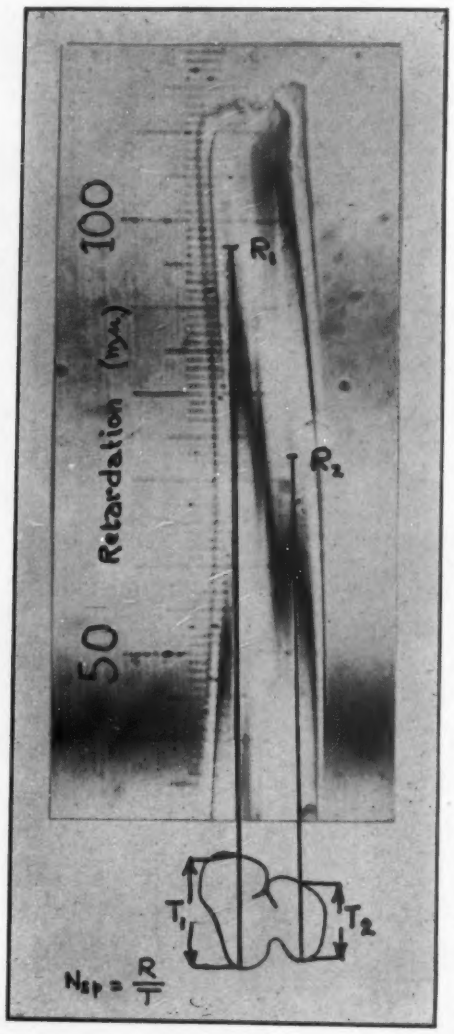
A PHOTOGRAPHIC method of charting the night winds high above the earth, to determine direction and velocity for weather forecasting and aircraft operations, has been worked out in the meteorological laboratory of Technology.

Devised by Athelstan F. Spilhaus, of the Woods Hole Oceanographic Institute, who is now carrying on research at Technology, the photographic method of nocturnal wind soundings was announced at the meeting of the American Meteorological Society at the United States Weather Bureau here this afternoon.

The method makes use of a "whole sky camera," which has a 180-degree lens; a pilot balloon and magnesium flares attached at intervals to a length of ordinary blasting fuse. From an observation point on the earth the camera lens is pointed upward, and, as the sounding balloon ascends, the flashes of the magnesium flares, ignited at known intervals are recorded on the plate. The photograph taken by the 180-degree camera is circular, the circumference depicting the horizon all around, and the brilliant magnesium flashes are registered on the plate regardless of the direction in which the balloon moves. Thus, by measuring the angles of elevation and direction between the camera station and the flashes, and correlating this data with the rate of ascent of the pilot balloon, an accurate record of the wind velocity and direction is obtained.

The usual method of measuring winds of the upper atmosphere, which often blow in the opposite direction to the surface winds, is to release a hydrogen-filled balloon and follow its course by means of a theodolite on which the angles of elevation and direction are read every half minute or minute. At night it has been the practice to suspend a paper lantern containing a candle from the balloon and to train a theodolite on the light. The disadvantages of this method, however, are that the light is extremely dim and is frequently lost in a short time. Observers have also been known to confuse the faint light of the lantern with stars. The Spilhaus method makes it possible to take readings photographically at very brief intervals, and the apparatus may be used by inexperienced observers. All that is necessary is to open the shutter of the camera and release the sounding balloon after lighting the fuse to which the magnesium flares are attached for any desired flash interval. Tests of the new method have been carried on for several weeks through the co-operation of the new Dewey-Almy Chemical Company, which supplied a new type of sounding balloon. Test plates for recording the magnesium flashes at distances of as much as seven miles and at heights of over 13,000 feet have been made. It is expected that this distance and height can be greatly exceeded.

In the field of meteorological research the Spilhaus method of nocturnal soundings will provide a means of making detailed studies of the structure of the winds. The intervals of observation can be reduced to five seconds for such investigations, an interval far too brief for theodolite observations.




***Contour diagram of rayon filament in polarized light with bi-quartz compensator and the actual cross section shape.***

## COURSE II — Textiles

RESEARCH in the field of fibre structure is being pursued in the Textile Laboratory by means of polarized light, among other methods. All textile fibres are birefringent, and the specific index of birefringence is indicative of the physical properties of the fibre. Problems dealing with molecular and fibrillar orientation of considerable importance to users of both natural and synthetic fibres are being studied by investigating the variations in the maximum and minimum refractive indices as fibres are stressed or altered in structure. One technique of interest is concerned with the determination of the specific index of birefringence. Ordinary immersion methods do not yield the desired value, but by equipping a petrographic microscope with a bi-quartz graduated compensator, a rayon filament can be made to draw its contour diagram on its own surface. A cross section of the fibre is prepared on a microtome, enlarged to the same scale, and photographed or drawn. The retardation read from the contour diagram, divided by the thickness of the fibre at the corresponding location, is the specific index. The individual rayon filament shown in the photomicrograph is nearly invisible without the use of a microscope.

## COURSE I — Civil Engineering

WITH increasing knowledge, the explanation of concrete shrinkage is becoming more and more of a problem. The tendency of gelatinous materials such as are contained in hardened concrete to expand upon wetting and to contract upon drying seems to be fundamental. Thus the shrinkage of a cement paste appears to be about as great as would be expected from the nature and amount of the gel it contains. For concrete it was first reasoned that the addition of aggregate to the cement mixture would reduce the shrinkage in some relation to the rigidity of the aggregate, the relative volume of the aggregate, and the volume constancy of its particles. Two years ago in the Technology laboratories, it was found that ordinary concretes contracted upon drying more than could be predicted by such reasoning. While some aggregates, like the dolomite used to build Norris Dam, produced concrete exhibiting only about as much shrinkage as was predicted, most others, including the aggregates available locally, were not nearly as effective as predicted.

It was then seen to be incorrect to neglect the degree of contact between the cement paste and the aggregate particles as a factor influencing shrinkage. In fact, thin sections were cut from various concretes, and observations showed that the contact between paste and aggregate was best when the shrinkage was lowest. It was clear that the aggregate could not reinforce the paste well against shrinkage when it was not adequately joined to the paste. After all, the average shrinkage of concrete, however detrimental, is only about a half-inch per hundred feet of length.

In order to follow up the progress gained, studies were made of the strength-producing qualities of the same aggregates that caused widely different shrinkage in concrete. After making corrections for differences in water requirement, it was found that there was a fair inverse ratio between concrete strength and shrinkage. When there was also taken into account the fact that increased rigidity of aggregate has a larger effect upon the reduction of shrinkage than upon the development of strength, the correlation appeared to be excellent.

While the studies of concrete shrinkage are only in their scientific beginning, it seems that it will be possible soon to predict the shrinkage of concrete from its known composition. Better still, it may be possible to dictate what shall be the properties of aggregates and of cements to produce minimum shrinkage. A most promising possibility seems to be the treatment of an inferior aggregate to encourage its bonding to cement paste and thus developing higher strength and lower shrinkage.

## COURSE II — Mechanical Engineering

THIS summer for four weeks, beginning June 21, the Mechanical Engineering Department is sponsoring the following special program on Strength of Materials:

PROGRAM

*Lectures on Creep*, by

A. Nadai, D. Eng., Westinghouse Electric and Manufacturing Company — nine lectures

F. H. Norton, Massachusetts Institute of Technology — one lecture

C. R. Soderberg, Westinghouse Electric and Manufacturing Company — two lectures

(*Continued on page 111*)

# PROPELLER STRESSES

(*Continued from page 95*)

phase relations were satisfactory, calibration was uncertain.

Piezo-electric and varying capacity methods were considered, but only the former was tried out. A commercial form of Rochelle salt pick-up, used in connection with electric reproduction of phonograph records, was called to our attention by Lycoming, and seemed suitable, but the units proved to be too delicate for use on engine-driven propellers. The piezo-elęctric pick-up is, however, very light and measures stress directly instead of in terms of acceleration. It has a very high energy output and is suitable for use with slip rings. In the presence of both torsion and bending, the stress analysis is complicated, as the device responds to both types of strain.

In 1936, a new line of experiment was opened up by E. H. Hull of the General Electric Company, who had successfully used the change in resistance of a strip of conducting paint under vibratory stresses.

In its first form, this pick-up consists of an insulating layer of paper cemented to the metal surface, and carrying lead-in contacts of tinfoil cemented to the upper surface of the insulating paper. The paint, applied between the two contact strips,was made of very finely divided graphite, either in water or alcohol suspension.

The steady resistance of the strip varies in an irregular manner at zero load due to temperature, moisture and perhaps other disturbances. To avoid this difficulty, the strip was connected so that only the change in resistance with strain was measured. If the stress variation is above 300 cycles per minute, the amplifier only records the cyclic fluctuations and is not sensitive to slow changes in resistance.

Calibration of such strips at the General Electric Company, at Hamilton Standard Propeller, and at the Massachusetts Institute of Technology, showed that the measurement of strain was almost independent of frequency and closely proportional to strain amplitude. The resistance could be made quite high, 1000 to 50,000 ohms, and a considerable voltage applied to the system. In this way slip ring difficulties were largely avoided. The weight of the pick-up was infinitesimal and the measurement could be carried out anywhere on the blade, regardless of the centrifugal loading.

The major difficulties were the necessity for calibration of each paint strip under vibratory stresses, and the change in sensitivity due to temperature and moisture. The device is, in effect, an extreme refinement of the carbon pile telemeter as originally developed by Peters of the Bureau of Standards and marketed by Baldwin Southwark Company for the last ten years.

It seemed desirable to develop a very light strain-sensitive resistance unit which could be manufactured under reproducible conditions, calibrated, and attached to the propeller without the requirement of a dynamic calibration after attachment. The study of such methods was undertaken both at Hamilton and by the author at the Massachusetts Institute of Technology. One of these methods which showed good possibilities was a mixture of sulphur and graphite with molded-in leads. The resistance was easily controlled and the dynamic sensitivity fairly stable. The resistance changes were sufficiently reproducible to lead us to hope that static calibration would be sufficient. However, the static behavior was thoroughly satisfactory; the change in sensitivity, due to temperature, was troublesome; and the units were found difficult to attach and remove without changing to some extent the calibration.

Ultimately, a pick-up, which fulfilled the desired conditions to a degree which permitted a practical and accurate continuous recording of propeller stresses in flight, at any selected points of the hub and blades, was evolved in the form of a granular, baked carbon composition. These pick-ups proved to be stable to a high degree and could be calibrated under

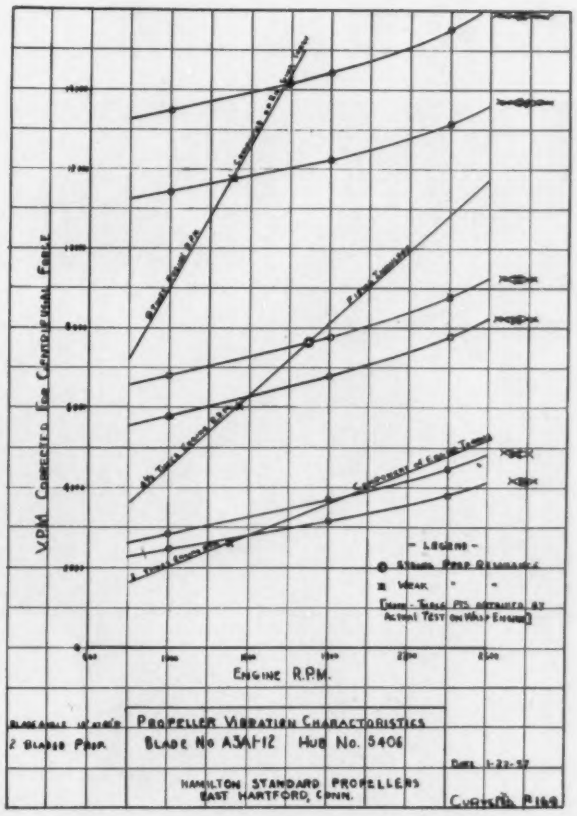



*Fig. 7. Natural periods of vibration of blades with and without centrifugal load. Vibrations with rotating flywheel, and in flight.*

static loads in the laboratories and later transferred to vibrating members without too much change in calibration constant.

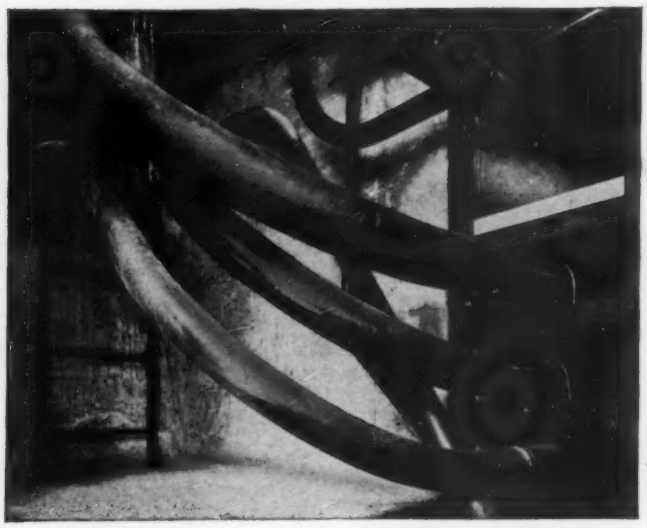
For example, using two pick-ups in corresponding positions on the opposite blades of a propeller, continuous studies of the various changes in modes of vibration and resulting stresses under any desired operating condition were possible. Figure 6 shows two sets of oscillograph records taken under the foregoing conditions. In one case the propeller is on the test stand and in the other in flight. Resonant conditions of both the in-phase and the out-of-phase type of vibration are clearly shown. The change of resistance of the pick-up units is amplified and the records made using equipment developed by Draper at M.I.T. and built by Sperry.

Figure 7 gives a plot of the natural periods of vibration of a pair of propeller blades with flywheel excitation and the same periods as indicated during flight. The necessary correction for centrifugal loading is here well indicated for the first time.

In some cases the tuning for resonance is broad, extending over a couple of hundred revolutions per minute, while in other cases the tuning is much sharper and suggests resonance between a propeller period and one of the forms of motion of the crank shaft. Much more investigation is necessary to locate the exciting forces under all conditions. In the first place, the motion of the engine in space must be considered, and in the second place, the various modes of vibration of the engine crank must be known definitely.

Suitable directional accelerometer units and torsional vibration units have been developed by Draper and Bentley of the Massachusetts Institute of Technology. It is to be expected that a combination of these instruments with dynamic strain measurements of all important parts of propeller and engine will lead to a much better understanding of the origin of propeller stresses than has heretofore been possible.

# ENGINEERING DIGEST



## WELDED PIPES

THE definite need for a system of standard practices in pipe welding has been met recently by the formulation of a detailed Code for Pressure Piping. Approved by the American Standards Association, the Code sets forth the basic requirements of pipe construction, and thoroughly discusses the welding process which it finds permissible for piping that is subject to all conditions of temperature and pressure. New minimum standards for steel and wrought iron welded pipe will allow considerable savings in material. Compared with former standards, the weight reduction in the eight-inch size is twenty-two per cent; in the ten-inch size thirty per cent; and in the twelve-inch size as high as thirty-three per cent. Unsuitable for threaded joints, the lighter piping now finds ready use when welding is employed.

The eight-inch welded pipe will serve under pressures up to 270 pounds per square inch at temperatures below 450 degrees Fahrenheit. Although the wall thickness of the lighter pipe is only one-quarter inch, the fact that welded joints are in excess of this dimension should enable the useful life of the thinner piping to compare quite favorably with heavier lines employing threaded connections. The ability of welded pipe to serve under all conditions is well demonstrated by a new four-inch line, shown in the accompanying illustration, which carries water at a pressure of 3,500 pounds per square inch, for the operation of an hydraulic press. The wall thickness is eleven-sixteenths of an inch.

*— Oxy-Acetylene Tips*

## CONDENSER TUBES

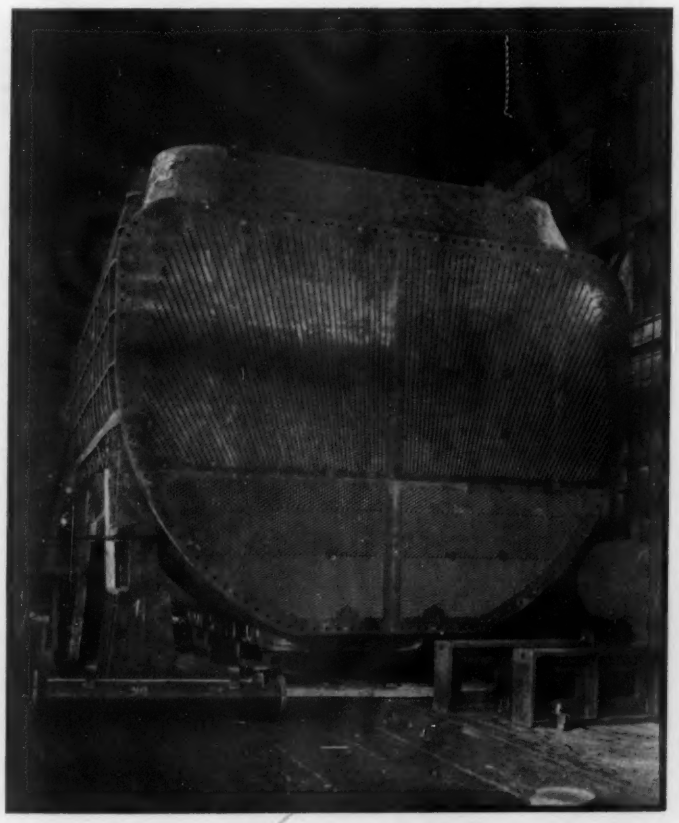
CONDENSER tubes are the lungs of a power plant. Their task is to fit exhaust steam for further service as boiler water. Literally miles of these tubes are essential auxiliaries to power plants on land and sea. Exposed constantly to corrosion, erosion, and varying temperatures, they must function without failure to prevent costly tie-ups and repairs. Because of their importance, few products of non-ferrous metal have received more specialized attention.

In selecting an alloy for use in condenser tubes, consideration must be given to the ability of the alloy to withstand the chemical attack of the media to which the tube will be exposed. The operating conditions of the particular unit must then be studied for the purpose of estimating the probable influence of erosion, impingement, cavitation, entrained air, suspended solids, and temperature of operation.

In recent years, the tendency has been to increase the velocity of cooling water circulation for greater efficiency in power plant condensers. Marine design requirements also call for maximum service with a minimum weight of cooling water, thus necessitating increased velocities.

Such high velocity has emphasized the ability of specific tube alloys to resist impingement and erosion. The older alloys, such as Admiralty, are failing rapidly under the new conditions. The British Admiralty, trying to develop an alloy that would form a tenacious, adherent, protective film on its surface when exposed to the corrosive influences normally present in a marine condenser, has produced cupronickel condenser tube containing about 70 per cent copper and 30 per cent nickel which, in addition to forming a protective film on its surface, provides an inherent resistance to destructive action of metal ion concentration cells, resulting from differential velocity conditions. This alloy has been adopted in the British navy and in shipbuilding circles.

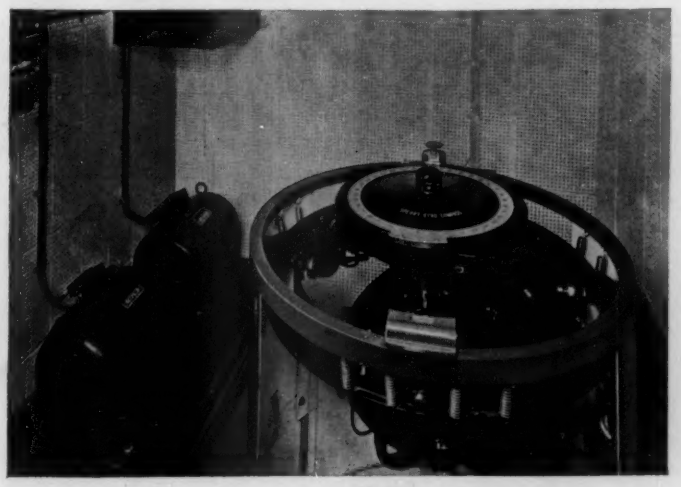
*— Inco*



## AUTOMATIC NAVIGATION

THE problems of navigation have been greatly simplified by the use of gyrocompass and gyropilot on transatlantic steamers, and by the aeronautical gyropilot permitting automatic course control in airplane flights. The father of these modern navigation instruments on sea and in the air is the simple gyroscope pictured with this article. Persistent work by Dr. Sperry has developed this simple gyroscope from a toy to a piece of perfected mechanism that is almost unbelievable. The other illustration shows the latest type gyrocompass used on the *Queen Mary*. It is the "brain" or "nerve center" of the huge vessel's automatic navigation system and always holds "true" north because it is unaffected by the magnetism of the ship, electrical disturbances, cargoes of metals, or motions of the ship. The latest addition is the automatic compass or "metal mike" which is actuated by the gyrocompass and which operates electric steering motors in the ship. Once a course is set the "metal mike" will maintain it with unerring accuracy. The gyro-horizon and direction gyro for airplanes are both offsprings of the toy gyroscope. The gyro-horizon, an horizon in the cockpit, shows by means of a miniature airplane and gyro-operated bar a plane's horizontal position with respect to the earth, indicating banks, glides, and climbs. The gyroscope has by its many recent adaptations to navigation come to signify security and comfort to all.

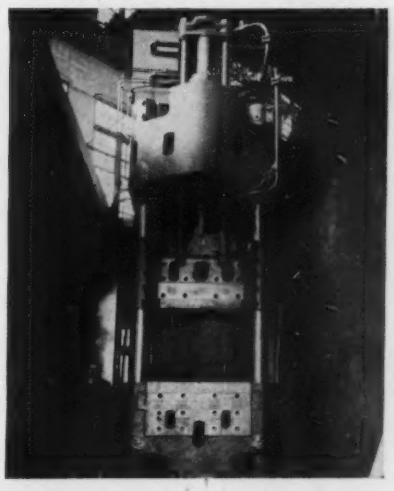
— *Inco*



## AIRPLANE CONSTRUCTION

ACCORDING to legend, Glenn Curtiss built his first airplanes with a hacksaw and hammer for his chief equipment. Thereafter, the construction of airplanes was fo many years chiefly a matter of skilled craftsmanship. The advent of larger dimensions and all-metal construction of aircraft today has brought about the use of numerous industrial and production devices. One such device is one of the largest hydraulic presses ever built, which will be used to shape strong aluminum alloy parts for metal fuselages and wings. Constructed in the East, the press required five railroad cars to move it to California. It weighs 175 tons, rises to a height of almost twenty-six feet. The pressure of 2300 pounds per square inch, which is developed hydraulically in one 38-inch ram and in two 20-inch rams, results in a force of 2000 tons on the aluminum alloy parts being formed. The closing speed through the 36-inch stroke is 130 inches per minute; the pressing speed varies from one to ten inches per minute. The operation of the press is governed with great simplicity by hydraulically-controlled operating-valves, a push button to start and stop the motor, and two gauges indicating the pressure on the rams.

— *Scientific American*

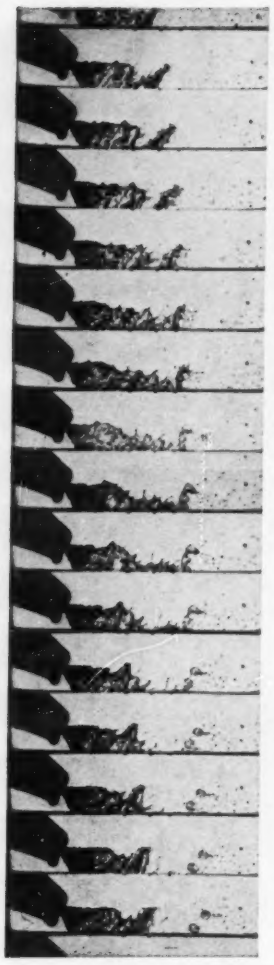


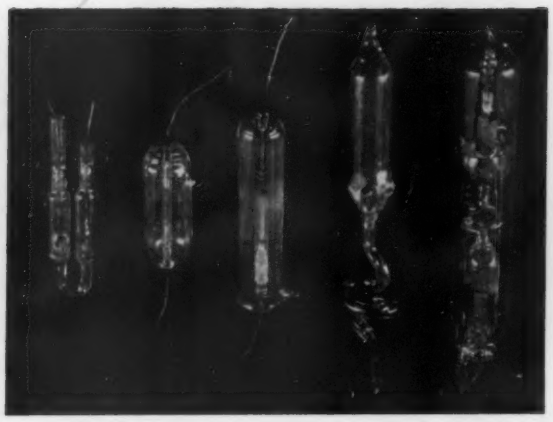
## HIGH SPEED PHOTOGRAPHY

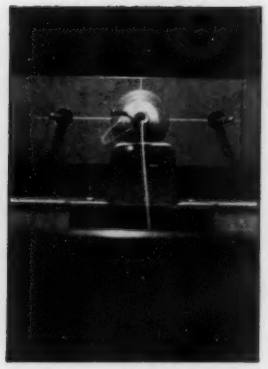
ALTHOUGH complicated methods of high-speed photography have been in use for many years, especially with silhouettes in the ballistic field, electronic devices have only recently made significant improvements possible in the apparatus. The basic principle of the new devices is the violent discharge of an electric condenser through a gas-filled tube or gap, resulting in an intense flash of light of very short duration at the instant of discharge.

Of the two general types of high-speed photography, that using the single-flash apparatus is the simplest. It takes but one picture at a time. The flash, the brightest of which is given by a tube filled with argon at atmospheric pressure, occurs when a high-voltage impulse is applied to a third electrode near the discharge gap. The flash lasts about $10^{-5}$ second, but is bright enough to expose adequately the common grades of film.

With high-speed motion-picture apparatus a series of photographs of very short exposures can be made at high rates of speed, and then projected in slow motion. The stroboscopic camera exposes 1200 frames per second with





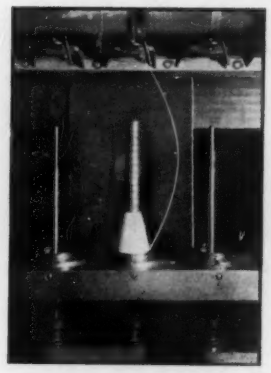


almost any standard lens. Illumination is provided by bright argon lamps in series with mercury-control tubes, which enable the argon lamps to be flashed at high frequencies. The chief disadvantage of this apparatus is its inability to record self-luminous objects. To photograph such subjects a camera with a moving optical system is used. The image is cast either by rotating lenses, rotating mirrors, or rotating prisms, and is held stationary with respect to the continuously moving film; the intermittant mechanism of the common movie camera is thus eliminated. Only ordinary lighting equipment is required, the exposure time being very much longer than with stroboscopic light.

The new apparatus is compact and portable. For this reason its already extensive use in industry is growing steadily.

— *Journal of Applied Physics*

## COTTON SPINNING



THE high-speed photographs in the upper right-hand corner of the page show the usual balloon effect that is obtained in spinning cotton yarns. A hindrance in ring spinning, this balloon formation limits the spindle speed and produces hairyness on the yarn. A recently announced improvement in the form of the "Freund" spindle construction eliminates the balloon, thereby greatly diminishing harmful yarn tension, centrifugal force, and air resistance of the ballooning yarn. Most important of all, the "balloonless spindle" makes possible the spinning of very soft twist, hitherto possible only on mules, on the regular and productive ring spinning machine.

— *Rayon Textile Monthly*

## PRECAST CONCRETE BLOCKS

SINCE 1929, a Cyprus mine has been lining its permanent tramming and ventilation galleries with precast concrete blocks. Chief advantages gained through the use of this type of ground support are a reduction of fire hazard, and improved ventilating conditions due to the diminished friction between air and the walls of the tube.

The blocks, which, according to their use, range from five to eight inches in thickness, cost less per cubic foot than most foundation work. Since the concrete tends to crack when the pressures on it are very great, the blocks are reinforced with steel. Consequently, replacement is necessary only when the blocks are badly crushed and crumbled; in the Cyprus mine only seven and a half per cent of the blocks has required changing since 1929.

The cut shows a typical completed gallery in which the joints in adjacent rings are staggered to give stronger support. Footblocks have been used to give greater depth and to allow for a drainage channel.

— *The Mines Magazine*

## GLARE

(*Continued from page 87*)

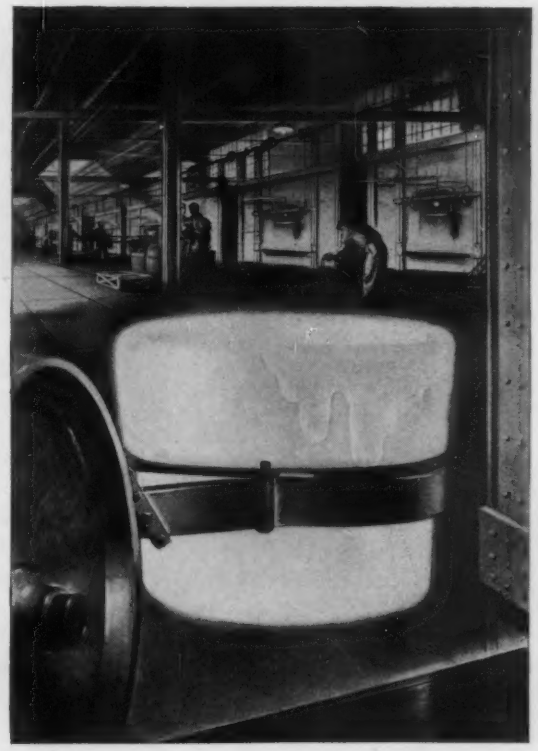
Evidently the polarizing disc used by the driver should not be incorporated permanently in the windshield but should be in some removable form so that it can be dispensed with in the daytime when it will generally be of no use whatever. But as soon as one thus makes the use of polarizing goggles or polarizing visor optional, he runs into a psychological difficulty. It seems to be a human characteristic to never deliberately reduce the brightness of objects (except perhaps in direct sunlight). A driver gets into his car at night. His eyes are adapted to the brightness of the pavement before him. Will he now deliberately interpose in his line of sight a polarizing device which reduces to ⅓ the brightness of all objects? He should do so because the polarizing medium will eliminate glare from oncoming cars whose headlamps are polarized. But will he?

***Duanesburg Road, Route 7, Schenectady County, New York—the longest stretch of sodium lighted highway in the world.***

The question of new laws also enters. By the very nature of the polarization scheme, a driver gains nothing by equipping his car with polarizing discs unless other cars are so equipped. Evidently if polarization is to be used, legal action will be necessary to compel all cars to be so fitted. Moreover, present legal restrictions on the size of lamps and the shape of the beam must be removed if the new material is to be used effectively. And if these changes are made and the headlamp candlepower is raised to perhaps ten times its present value, what will happen to the unfortunate pedestrian who has ventured out after dark without his polarizing glasses?

This glaring picture of difficulties connected with the use of polarized light for motor vehicles does not by any means imply that polarization is impracticable. It does mean, however, that we shall not eliminate headlamp glare tomorrow or next week. The elimination of glare may be just around the corner, but, as with television, practical obstacles may prevent it from getting around that corner for several years. Irrespective of what is done with motor-car headlamps, important trunk highways can and should be made safer and more pleasant by the use of correctly-designed lighting from fixed lamps, and the new sodium and mercury lamps can be used effectively in many cases. The two general methods — fixed lamps and moving lamps — are complementary rather than antagonistic. Light sources attached to the moving car can never provide the high quality of illumination that can be obtained from fixed lamps. On the other hand, it is doubt-

(*Continued on page 107*)



MATERIALS

A product is only as good as the materials which go into it. This is especially true of optical instruments wherein every section of a lens—the surfaces and all of the glass between them—plays an active part in the performance of the instrument.

The Bausch & Lomb Optical Co. is the only optical manufacturer in America which operates its own glass plant. The purpose is to have complete control over the glass used in B & L instruments. It is justified by the excellence of the products and the satisfaction expressed by users.

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# CALCULATING MACHINES

(*Continued from page 92*)

units, respectively. In line with either of these tens or units groups were the ends of nine parallel-toothed racks, which moved under pinions connected to the figure wheels. When the tongue plate was rotated, the tongues pushed their respective racks through a distance depending on the lengths of the tongues. The pairs of tongues on the "6" plate, for example, corresponded, in cogs through which each rack rotated its pinion, to lengths of 0,6; 1,2; 1,8; 2,4; 3,0; and so on. If six were to be multiplied by four, the carriage was moved to the extreme right, levers set to 6 and to 4, and the handle turned only once. The fourth rack was thereby pushed through two pinion teeth by the short seventh tongue, so that a 2 appeared in the tens results column; the carriage moved a step to the left; then, the rack having been returned to its original position, a longer tongue pushed the same rack through four teeth, so that a 4 appeared in the units place of the result column, showing that the required product was 24. Only one turn of the handle was required for each figure in the multiplier.

To perform division on multiplication machines, the reciprocal of the divisor is usually used as a multiplier. There is a machine, however, which is designed for direct division; it accomplishes the operation by successive approximations ot the true value of the quotient from above and below.

Improvements are being made with the general purpose of making the operation of the machines entirely automatic, once the numbers and the operation required have been indicated to it. Electric motor drives are replacing handles, although machines of the former type usually have shorter lives than those of the other. Keyboards, with automatic devices insuring higher speed and accuracy in the setting operation, have almost entirely superseded the slide-board. In a newer kind of machine than those already described, operating by the "Barbel" method, the rapid counting of steel balls is utilized.

There are other types of calculating machines which are designed to perform operations a bit more complicated than those four of elementary arithmetic. Probably the first such device was invented in 1812 by an Englishman named Charles Babbage, for the purpose of calculating and printing mathematical tables. It was called the "Difference Engine," since its underlying principle was the method of differences. This method of differences applied to the squares of numbers, for example, states that the second difference of consecutive squares is always two. This theorem may be made clear by figure 6, where the differences between the squares appear in the column of first differences; obviously, the second differences, or the differences between the first differences, are in every case two. The machine had merely to perform simple additions to obtain the whole series of successive square numbers.

The Difference Engine was an "expression of one particular theorem of analysis," however, and was unable to perform other types of operations. Seeking a more versatile calculator, Babbage began work on his Analytical Engine in 1833, before his other machine had been completed. His newer device was intended to evaluate automatically any mathematical formula, while making use of two principles — first, that every mathematical calculation ultimately depends on the four basic operations of arithmetic; and second, that it is possible to reduce every mathematical calculation to that of the coefficients of the various terms of a series. As a simple example, if the equations

$$\begin{aligned} (m\ x + n\ y &= d \\ (m'x + n'y &= d' \end{aligned}$$

were given, and it was desired to solve for x, x would be found equal to $\frac{dn'-d'n}{n'm-nm'}$. In order to determine the value of x, the machine had to be able to do two things — first, to execute arithmetical calculations, and second, to distribute correctly the values thus obtained. These two operations were controlled by cards with specially punched holes, similar to those used in Jacquard's brocading apparatus, which were fed into the machine. In determining the above value of x, the cards would successively cause the machine to find the products of d′n, dn′, n′m, and nm′; then the differences indicated; and finally the quotient of the differences. Unfortunately, Babbage died, in 1871, before either of his machines was completed. A number of difference engines were designed and successfully used by others, however.

Another type of calculating machine is that which deals with curves and graphs rather than with numbers. Such is the Institute's product integraph, developed a number of years ago. Its most important use is the solving of ordinary differential equations, giving prompt solution to problems that can be formally treated only by extremely laborious processes. Its preliminary multiplying of any two curves may be followed by any number of integrations, thus raising the order of the equation solvable. Results are automatically given in the form of a curve or a family of curves with a precision of from one to two per cent.

In the same class is Dr. Bush's differential analyzer, which is employed to a large extent in the solution of complex differential equations in the fields of electrical engineering and mathematical physics. All the main integration operations are mechanical, while the drives and controls are electrical. A few hours are usually required to set up the machine for a given problem; the time for solution varies with the complexity of the problem and with the precision desired, of which the average high is somewhat less than one part in 1000. The machine could not be called completed, since it is always possible to extend it.

Recently John B. Wilbur completed a simultaneous calculator at the Institute. Containing over 13,000 parts, it is capable of quickly solving nine simultaneous equations. It was developed to eliminate delays in the solution of complicated engineering problems, such as computing the stress on steel bridge sections.

It may be seen, then, that a calculating machine has three distinct advantages. It eliminates chances of error; it saves time; and it provides what Babbage called economy of intelligence — the replacing of intellectual labor which may be more profitably employed. Calculators have virtually revolutionized office work; and they have speeded up, and often made possible, the solutions of problems in the various branches of science. Their potential benefit to mankind is limitless.

## GLARE

(*Continued from page 105*)

ful if lighting from fixed lamps will ever be economically feasible for all roads. Judging by the number of valuable developments now in progress one can predict that in another decade our highways will present a radically different picture at night from what they do now.

TABLE I.

*Incandescent Lamps for Series Operation*

| *Lumens* | *Amperes* | *Volts* | *Lumens per Watt* |
|---|---|---|---|
| 2,500 | 6.6 | 22.2 | 17.1 |
| 4,000 | 6.6 | 33.9 | 17.9 |
| 6,000 | 6.6 | 51.1 | 17.8 |
| 6,000 | 20 | 15.3 | 19.6 |
| 10,000 | 20 | 25.0 | 20.0 |
| 15,000 | 20 | 37.9 | 19.8 |
| 25,000 | 20 | 60.7 | 20.6 |

TABLE II

*Vapor Lamps made in the United States*

| | *Sodium* | *Cooper-Hewitt* | *Mercury* | | |
|---|---|---|---|---|---|
| | | | *H-1* | *H-2* | *H-3* |
| Tube diameter (cm) | — | 2.4 | 3.5 | 2.5 | 0.4 |
| Arc length (cm) | 23 | 128 | 16.0 | 10.5 | 1.8 |
| Vapor pressure (atm) | — | 0.0003 | 1.4 | 0.4 | 28.5 |
| Volts | 25 | 71.9 | 150 | 67.5 | 251 |
| Amperes | 6.6 | 3.70 | 2.77 | 4.06 | 0.401 |
| Lumens | 10,000 | 6500 | 16,000 | 7000 | 3400 |
| Lumens per watt (exclusive of losses in auxiliary equipment) | 60 | 24.5 | 40 | 28 | 39.5 |


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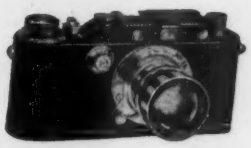

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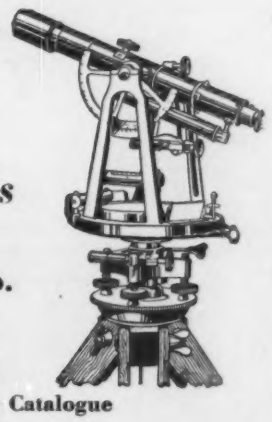

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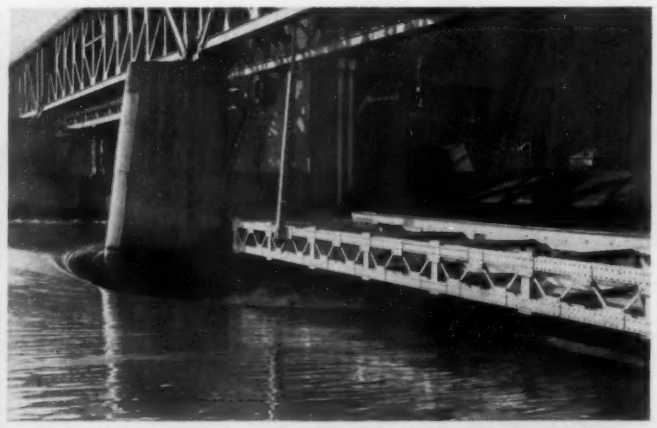
# ALUMINUM

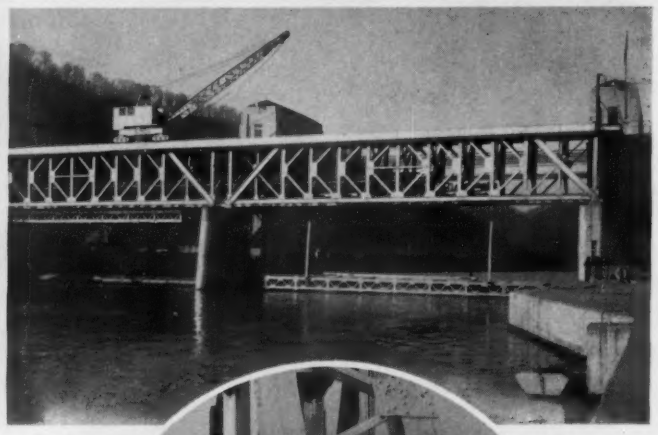
(*Continued from page 90*)

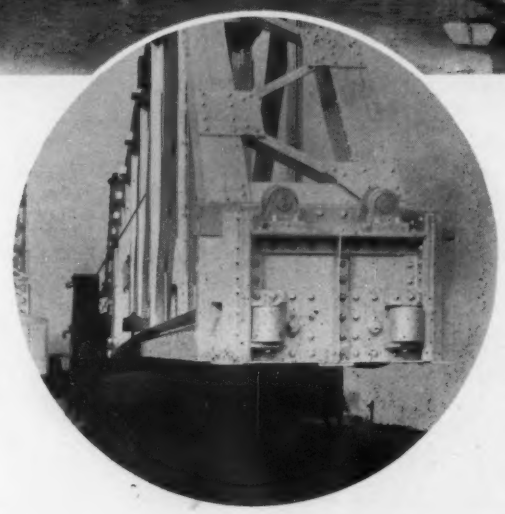
aluminum alloy dipper; two dipperfuls would fill a standard 50-ton railroad hopper car. During 1936, this machine handled 6,300,000 cubic yards of earth, a volume nearly twice that of the concrete in Boulder Dam.

Power-shovel dippers are subjected to severe and indeterminate working stresses from the moment the teeth bite into a bank of dirt and boulders until the door bangs shut after the load is dumped. To stand up under a life of twisting and wrenching and under impacts of huge boulders falling from high up on the bank, a dipper must be unusually rugged. In the construction of a conventional steel dipper, about 4,000 pounds of structural material are required per cubic yard of capacity. By substituting aluminum, this figure is reduced to approximately 2,000 pounds per cubic yard, which permits an increase in capacity of about 30 per cent with no increase in the gross weight of the loaded dipper.

The first large aluminum dipper, a 16-cubic-yard unit, was made in 1934. Its design was based entirely on the operator's knowledge of working requirements, the manufacturer's experience in power-shovel construction, and the familiarity with the characteristics of aluminum alloys possessed by the producer of the light metal. The main body of the dipper consists of two 27S-T shell plates separated in the back by cast spacers, giving a box construction to take the thrust of the stick. The teeth, lip, and bottom band are manganese steel, selected because of its resistance to abrasion. The door plates and bail are aluminum alloy 27S-T. It it possible to compute the maximum load on the bail with greater accuracy than is the case with most other dipper parts, The electric hoist motors will stall at a given load, and by making the stall load and adding to it a moderate impact factor, the maximum load on the bail is obtained. Only a moderate impact factor is re-







***The roller gate dam at Marmet, on the Great Kanawha River, near Charleston, W. Va. An experimental aluminum bulkhead was made for this dam. The new device was so successful that it served as a model for the bulkheads later built for Gallipolis.***

# ALUMINUM

(*Continued from page 108*)

quired, since the long hoist cables can be counted on to absorb a portion of the shocks.

Door hinges and back-connection pads are 220-T4 castings. The back pads form the connection between the dipper body and the stick, and are subjected to loads of unknown magnitude as the dipper is forced through alternate strata of hard and soft material. The design of door hinges presents more of a problem than might be expected. It is a relatively simple matter to calculate the stresses arising from the weight of a load of dirt, but as the load is dumped it often swings the 3-ton door back against the bumper block on the stick, causing a terrific impact. This is just one of the indeterminate loads placed on the hinges.

In spite of difficulties of this nature, engineers have designed aluminum alloy dippers which operate 24 hours a day for month after month. The 32-cubic-yard aluminum dipper has been in service for 15 months and has required no repairs or replacements of any of the aluminum parts. This is a remarkable record for a piece of equipment subjected to such severe service. The designers had the benefit of previous experience with smaller aluminum dippers, but before fabrication could be commenced, several metallurgical problems had to be worked out. The specifications called for the rolling of 27S-T plate larger than any previously rolled and for the casting of the heaviest part ever made from No. 220 alloy. The plate weighed 2,400 pounds; the casting, 3,400 pounds.

Structural aluminum has played an important role in the development of long-reach dragline excavators. The first demand for machines of this type was created by the Government's extensive levee building program along the Mississippi River. Tremendous quantities of earth had to be moved short distances and the most economical method was to employ draglines equipped with large buckets on long booms. An increase in the size of these parts increases their weight and seriously decreases the stability of the machine against overturning. It also decreases the swing speed, thereby partially offsetting the advantage of larger capacity. However, by constructing the booms of aluminum alloy 17S-T, their weight is cut in half. An increase in length of 15 to 20 per cent is then possible without disturbing the operating characteristics of the machine. A long-reach boom eliminates considerable rehandling of dirt and under favorable conditions will increase construction speed 15 to 25 per cent. If increased reach is not desired, a 20 to 25 per cent larger bucket can be handled. Generally, only the outer section of the boom is made of aluminum. Steel is employed for the section next to the machine, since weight saving at this point is of secondary importance.

The design of a dragline boom is based much more on known loads and stresses than is the case with power-shovel dippers, but even so, an understanding of operating conditions and a knowledge of the characteristics of aluminum alloys are essential for efficient and durable construction. A boom is primarily a latticed strut subjected to heavy compression loads resulting from the weight of the bucket and dirt acting through the hoist cables and supporting guys. The maximum compression load is known within a reasonable degree of accuracy, as is the smaller vertical load caused by the weight of the boom. In addition, the boom is subjected to an indeterminate horizontal load resulting from acceleration and deceleration of the boom during each swing.

At the time the first aluminum boom was built (1930), little exact knowledge was available concerning the magnitude and nature of the swing forces. Models of built-up struts were

(*Continued on page 110*)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# ALUMINUM

(*Continued from page 109*)

tested to determine the distribution of stresses and considerable fundamental data were collected which are of value in selecting the most efficient type of strut and in arranging the various members. It was not possible to duplicate the swing action of a working boom, so, to obtain definite data on this phase of the problem, strain measurements were made on a boom in operation. Scratch strain gauges, which record strains automatically on a chromium-plated brass target, were employed. It was found that the stresses were considerably higher than previously estimated. The data collected from laboratory and field tests have aided materially in designing satisfactory light-weight booms.

The 240-foot boom built last year is used on a diesel-electric dredge for canal and levee work in the Atchafalaya Floodway, Louisiana. Instead of employing a conventional latticed strut design, the new boom is composed of a lower or compression member formed by two plate girders connected by a system of horizontal lacing. Steel cables form the upper or tension member and the two members are connected by a series of aluminum struts. Since each member has a single and definite function to perform, stress calculations are simplified and many of the uncertainties of loading are eliminated.

There are numerous other applications of structural aluminum — streamlined trains, overhead traveling cranes, buses, and trucks. Their design and fabrication have presented many problems, the solution of which has added to the general store of information on the light alloys. This backlog of fundamental knowledge and practical experience, combined with constant research and new developments in design and fabrication procedures, aids immeasurably in solving new and more difficult structural problems. The net result is a steady broadening of the field of application for structural aluminum.

## TABLE I

## TYPICAL MECHANICAL PROPERTIES FOR SOME ALUMINUM ALLOYS EMPLOYED IN STRUCTURAL WORK[1]

| *Alloy* | *Form* | *Tensile Strength (lb. per sq. in.)* | *Yield Strength[2] (lb. per sq. in.)* | *Shearing Strength[3] (lb. per sq. in.)* | *Elongation (per cent in 2 in.)* | *Density (lb. per cu. in.)* |
|---|---|---|---|---|---|---|
| 52S–½H | Plate . . . . . | 37,000 | 29,000 | 21,000 | 10 | 0.096 |
| 17S–T | Plate and structural shapes . . . . . | 58,000 | 35,000 | 35,000 | 20 | 0.101 |
| 27S–T | Plate and structural shapes . . . . . | 60,000 | 45,000 | 37,000 | 10 | 0.101 |
| 53S–T | Plate and structural shapes . . . . . | 38,000 | 32,000 | 26,000 | 14 | 0.097 |
| 14S–T | Forgings . . . . . | 65,000 | 50,000 | 40,000 | 10 | 0.101 |
| 220–T4 | Castings . . . . . | 44,000 | 25,000 | 33,000 | 13 | 0.092 |

[1] Young's modulus of elasticity is approximately 10,300,000 lb. per sq. in.
[2] Yield strength is the stress which produces a permanent set of 0.2 per cent of the initial gauge length.
[3] Single-shear strength values obtained from double-shear tests.

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## RESEARCH IN REVIEW

(*Continued from page 100*)

*Lectures of Fatigue of Metals*, by
H. J. Gough, D. Sc., F. R. S., National Physical Laboratory, England — eleven lectures
A. V. deForest, Massachusetts Institute of Technology — one lecture
*Lectures on Strength of Materials*, by
J. M. Lessells, Massachusetts Institute of Technology — two lectures
I. H. Cowdrey, Massachusetts Institute of Technology — three lectures
R. W. Vose, Massachusetts Institute of Technology — three lectures
C. W. MacGregor, Massachusetts Institute of Technology — four lectures
*Laboratory Exercises on Strength of Materials*
*Seminars*
Structures of Portland Cement and Concrete
Structure of Metals
Geological Problems in Behavior of Materials
Instrumentation I
Instrumentation II
*Conferences*
Creep of Metals
Fatigue of Metals

Dr. A. Nadai, who will lecture on Creep, is a consulting engineer for the Westinghouse Electric and Manufacturing Company. He is well known both in Europe and in the United States for his research on plasticity and for the textbook, "Plasticity" (McGraw-Hill), which he has written. In 1931, he gave the Marburg Lecture before the American Society for Testing Materials. Through his work as a member


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## RESEARCH IN REVIEW

(*Continued from page 111*)

of the Applied Mechanics Division of the American Society of Mechanical Engineers, he has also contributed effectively to the better understanding of plasticity on the part of engineers. Mr. Soderberg, in his lectures, will treat design applications using plasticity theory.

Dr. H. J. Gough, who lectures on Fatigue, is widely known for his research on this subject. He is the author of the well-known book, "Fatigue of Metals" (Scott Greenwood), and gave the Marburg Lecture in 1933.

Among the men who will present papers at the Saturday conferences are Mr. E. L. Robinson of the General Electric Company; Dr. D. J. McAdam, Jr., of the Bureau of Standards; Professor H. F. Moore of the University of Illinois. The department expects an enrollment of from 25 to 50 men and a conference attendance of about 200.

Further particulars about the session may be obtained from Professor John M. Lessells, Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts, Director of the Program.


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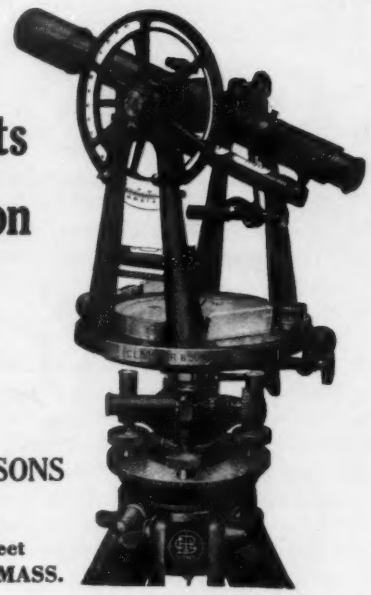

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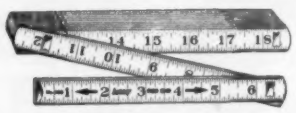

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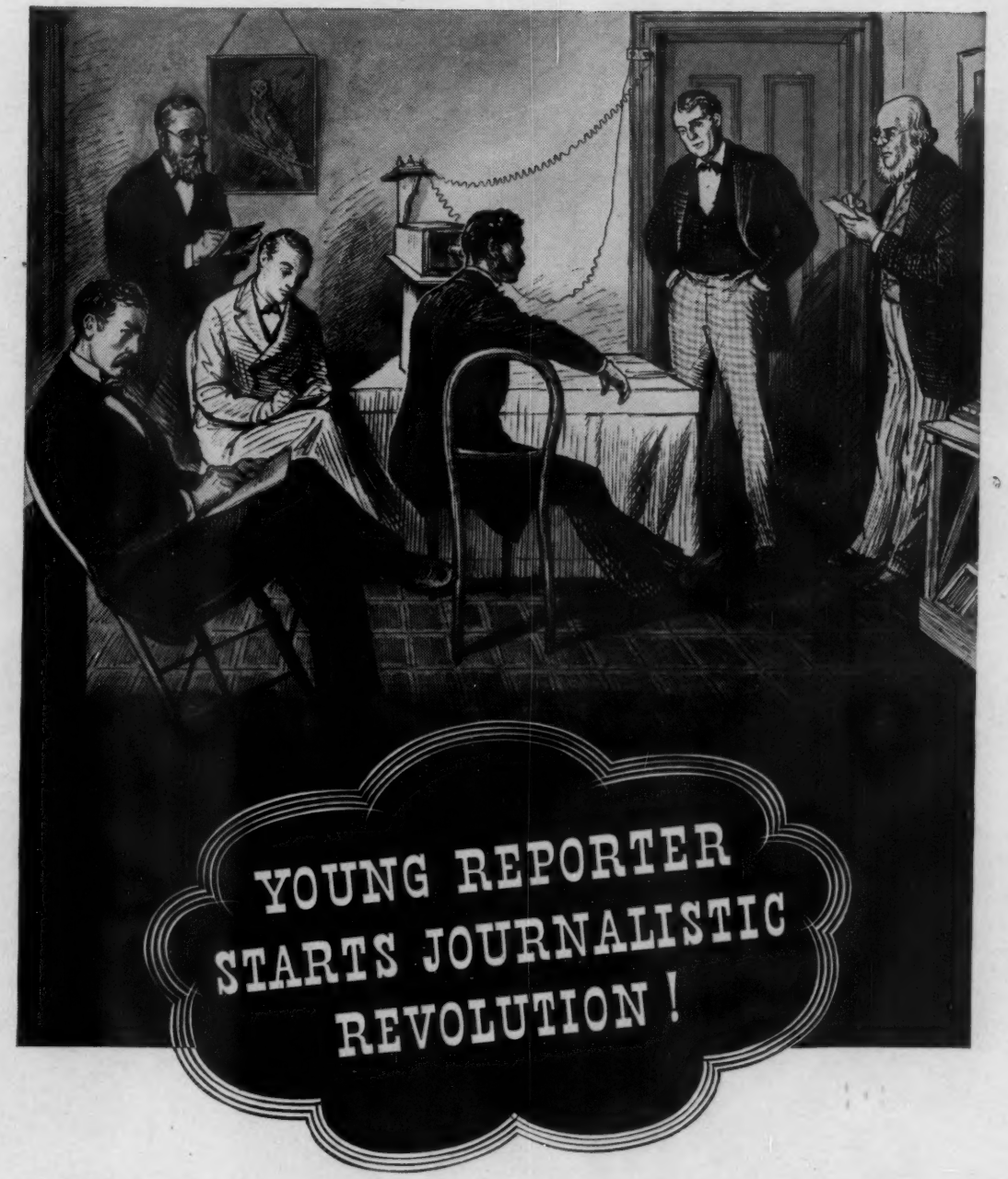

# YOUNG REPORTER STARTS JOURNALISTIC REVOLUTION!

It happened in Salem, Mass., on February 12, 1877. The young reporter attended a demonstration of inventor Bell's new telephone—then "talked" his story to his paper in Boston *by telephone!*

Though he didn't realize it, he was inaugurating a new era in journalism. For today's newspapers could hardly exist without the telephone.

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# G-E *Campus News*

## FOR OUTSTANDING ACHIEVEMENT

February 26 was a big day in the lives of thirty-three G-E employees. These thirty-three were selected from the 60,000 persons in the Company's employ to receive the Charles A. Coffin Awards. There were fifteen factory men, twelve engineers, two commercial men, and four administrative and clerical employees. Twelve of the group are college graduates:

Roy T. Adolphson, University of Washington, '34; Eugene W. Boehne, Texas A & M, '26, and M. I. T., '28; Claude P. Hamilton, University of Nevada, '14; George H. Jump, Syracuse U., '10; Jack R. Meador, Texas A & M, '27 and '28; Harry E. Scarbrough, Georgia Tech., '19; Edward J. Schaefer, Johns Hopkins, '23; Alfred A. Thompson, University of California, '05; Carl Thumin, College of City of New York, '17, and M. I. T., '20; Harold E. Trekell, Kansas State, '31; Elmer J. Wade, University of Maine, '19; and Leo F. Worden, West Virginia University, '25.

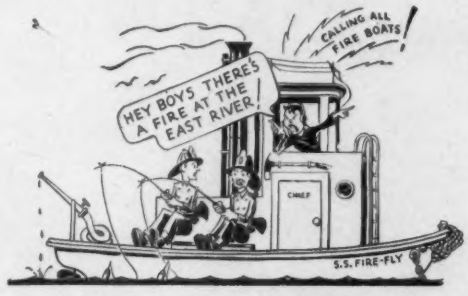
Each year General Electric makes these awards to employees who have done outstanding work, as provided in the Charles A. Coffin Foundation established in 1922. Charles A. Coffin was organizer and first president of General Electric.

## "EXPERIMENTALLY—NOT ON PAPER"

Sixteen years or so ago, Dr. Willis R. Whitney, now Vice President in charge of General Electric research, sent a note to a research worker, suggesting experiments with a motor-generator set sealed gastight and filled with hydrogen to see if the machine ran cooler, and more efficiently. The results of those experiments promoted the use of hydrogen in synchronous condensers and established the present trend toward the use of hydrogen in turbine-generators.

Windage loss in a rotating machine is reduced about 90 per cent and noise is greatly decreased because of the low density of hydrogen. Heat is carried away much more rapidly through the higher thermal conductivity of hydrogen. Resistance to damage due to corona within the machine is increased. These characteristics increase the electrical output for a given core size and reduce inspection and maintenance expense.

The construction of several hydrogen-cooled turbine-generating units is now going on in the Schenectady turbine shop—perhaps all because of that note written by Dr. Whitney so many years ago.




## CALLING ALL FIREBOATS

Fireboats are often away from their docks for several days at a time—not on a fishing trip, but fighting severe marine fires. The communication problem has been solved, however, for the fire-fighting sailors on the nine New York fireboats. General Electric engineers have installed a two-way radio system which will be in operation when the boats are out of telephonic contact with shore. This system will be an invaluable aid in expediting the handling of injured persons or those suffering from exposure.

In size, this system will be second only to the police-car system used in Boston. Two-way conversation will be possible, with no switching operations necessary to change from talking to listening. The equipment will include a remote-control, 500-watt, medium-frequency central transmitter for direct radio communication to all fireboats. The return part of the conversation from the boats will be transmitted by ultra-high-frequency radio to pickup receivers located at strategic points on the shore.

96-376DH

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